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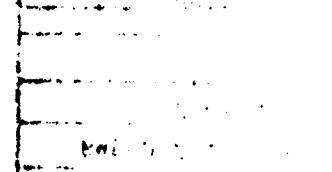
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AN EVALUATION OF MEASUREMENTS USED
TO DRIVE COMPETITIVENESS IN A DEPOT
MAINTENANCE ENVIRONMENT

THESIS

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AN EVALUATION OF MEASUREMENTS USED TO DRIVE

COMPETITIVENESS IN A DEPOT MAINTENANCE ENVIRONMENT

THESIS

Presented to the Faculty of the School of Systems and

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In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Logistics Management

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## Preface

This thesis started as an idea from the Air Force Logistics Command (AFLC), which wanted the Air Force Institute of Technology to study the implementation of Theory of Constraints measures at Air Force maintenance depots. While the study was in progress, AFLC combined with the Air Force Systems Command to become the Air Force Materiel Command (AFMC).

We would like to thank all the people at HQ AFMC/LGPP for their help in laying the foundations of this research. Also, we would especially like to thank the depot managers at Warner Robins Air Logistics Center for being frank, open, and gracious during our interviews. Next, we thank our thesis advisors, who urged us not to do things the easy way, but to do the best job possible.

We want to thank our parents, who raised us to believe that we could do anything, if we put forth enough effort. Finally, and most importantly, we would like to thank our long-suffering wives, whose ever-growing love, patience, and understanding made the past year bearable. We can never replace the lost time we could have spent together. We realize that each day represents a chance to make up for the loss, and we look forward to the birth of our new lives.

Jack A. Meyer, Jr.

Timothy A. Widowfield

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## Abstract

This thesis acknowledges that Air Force Materiel Command maintenance depots will face increased competition for workload, especially exchangeable items, both from other Service depots and from civilian contractors. The authors, through the literature review, identify quality, delivery, and cost as the three primary competitive edges firms can use to gain advantage in the marketplace. Further, a recent study confirms that Air Force depot managers also consider these three factors of competitiveness to be most important. The authors tested two depot measurement systems, the Defense Depot Performance Measurement System (DDPMS) and measurements based on the Theory of Constraints (TOC). During personal interviews, ten depot managers were asked a series of questions designed to discover whether they understood the constituent measures of the two systems and whether they found the measures useful for competing with respect to quality, delivery, and cost. The authors analyzed the managers' responses to the questions and found that neither measurement system related well to the three competitive edges. Also, according to the managers, neither measurement system, as a whole, was driving depot performance. A new measurement system combining measures from DDPMS and TOC with other measures was recommended.

# AN EVALUATION OF MEASUREMENTS USED TO DRIVE COMPETITIVENESS IN A DEPOT MAINTENANCE ENVIRONMENT

## I. Introduction

### Overview

For many years U.S. Air Force depots enjoyed a virtual monopoly in the heavy repair and overhaul of aircraft, missiles, engines, and exchangeables. Exchangeables include parts, subassemblies, and avionics "black boxes" that base-level units exchange one-for-one with their servicing depots. In the near future, maintenance depots will face competition from private firms who will be permitted to bid on exchangeable item repair (Owens, 1991). This thesis looks at the competitive challenge facing the depots. It examines two major performance measurement initiatives -- the Defense Depot Performance Measurement System (DDPMS) and an AFMC-sponsored measurement system based on the Theory of Constraints (TOC) -- to see how each drives performance to meet that competitive challenge.

This chapter gives a short background on depots and the imminent competitive threat they face. Next, it defines the specific problem confronting depots. Finally, it enumerates specific investigative and management questions, the answers to which may suggest solutions to the problem.

## Background

The monopolistic character of depot maintenance is changing. Under new funding initiatives, wing commanders will have greater freedom of choice regarding depot-level repair. Although depots will by necessity remain the single-source provider for aircraft and missile overhaul, private companies are starting to compete in the exchangeable market (Owens, 1991). This change will present new challenges (Hinneburg, 1991:ii).

The Air Force Materiel Command (AFMC) and its depots have recognized this new competitive environment as well as the consequences should the depots fail to win that competition. Figure 1.1 shows the sales revenues from the major categories of depot work. Over the five-year period FY 87 to FY 91, revenue from exchangeables has represented a little over half the command's total organic sales revenues.

| | FY 91 | FY 90 | FY 89 | FY 88 | FY 87 |
|---|---|---|---|---|---|
| SALES REVENUES (ORGANIC) | | | | | |
| Aircraft | 583,204 | 591,323 | 527,628 | 506,098 | 567,412 |
| Missiles | 43,992 | 43,264 | 52,723 | 52,287 | 60,950 |
| Engines | 219,571 | 218,067 | 220,992 | 215,744 | 271,035 |
| Exchangeables | 1,288,472 | 1,212,711 | 1,180,093 | 1,171,878 | 1,374,357 |
| Other Major End Items (OMEI) | 40,241 | 39,221 | 44,837 | 42,803 | 49,799 |
| Other Revenue | 271,224 | 228,052 | 230,381 | 202,552 | 421,433 |
| Total Revenue | 2,446,704 | 2,332,638 | 2,256,654 | 2,191,362 | 2,535,986 |

(Amounts in thousands of dollars)

**Figure 1.1: Five-Year Summary of Organic Sales Revenues
(Deputy Chief of Staff/ Logistics, HQAFMC, 1992:25)**

In fiscal year 1991 AFMC experimented by allowing private industry to bid against depots for five exchangeable maintenance contracts. The depots won two of those contracts (see Figure 1.2). The bidding depots who lost cited cost as a main reason they could not compete. Since depots must factor in operating costs and overhead into price per unit, while private bidders could offer a price equal only to material cost plus profit, private bidders could bid lower (Owens, 1991). Regardless of the cause, the loss of contracts in this test situation may augur future losses and is a concern.

| Workload | Air Logistics Center | Award | Winner |
|---|---|---|---|
| TF33 Vanes and Shrouds | Oklahoma City, OK | 3 Jul 91 | Chromalloy |
| F-16 OFP Software | Ogden, UT | 25 Sep 91 | Logicon |
| T56 Gearboxes | San Antonio, TX | 4 Sep 91 | Standard Aero |
| TRC-97A Ground Radio | Sacramento, CA | 25 Sep 91 | Sacramento ALC |
| ARC-186 UHF Radio | Warner Robins, GA | 27 Sep 91 | Warner Robins ALC |

**Figure 1.2: Results of FY 91 Competition: Private Industry vs. Air Logistics Centers (AFLC/LGPW-1, 1991)**

DoD officials need to decide whether continued loss of contracts is a desirable occurrence. If private firms suc-

ceed in taking business away from the depots, a prolonged decline in depot market share of exchangeables could occur. Market declines will inevitably lead to manning cuts and a loss in expertise and core competencies. Additionally, even if a particular exchangeable item is not substantially profitable, the reduction in the number of items repaired by a depot means that overhead for that depot must be spread out over fewer items, thereby increasing the cost (price) of all items.

It is important, then, for depots to hold on to the exchangeable market. To remain competitive Air Force depots must successfully compete with private firms to deliver products on the bases of speed (cycle and delivery times), cost, and quality, or they will face a steady erosion in their market share of exchangeable items (Glovka, 1992). A number of studies have shown that managers are aware of these foundations of competition. Kwolek's survey of depot managers at all levels revealed that cost (internal costs, operating costs, etc.), quality (number of defects), and delivery (on-time, defined by the customer) were the self-identified, top three "competitive edges" depots should strive to improve (Kwolek, 1992:454-466).

Product quality has become a major driver in the search for competitive advantages. Depot output is no exception. The recent thrust toward Total Quality Management (TQM) has placed a great deal of emphasis on product quality. To

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assess its output quality, depots rely on customer satisfaction data gleaned from Quality Deficiency Reports (QDRs). While all manufacturing and maintenance organizations can profit by surveying their customers regarding the quality of delivered goods, the QDR system suffers from major problems.

Foremost among these problems is the tendency for wing-level customers to underreport defects. C. W. Smith, a researcher for LSA, noted several reasons why bases do not report defects. They include:

- Information required on the form is not available to the user (e.g., contract number, unit price, or manufacturers' part number).

- Lack of faith that the system will get the problem corrected.

- Dislike of paperwork.

- [Receiving an] answer considered nonresponsive by customer such as, "This is an isolated case; no trend has been established." It was noted as especially frustrating to receive this answer after submitting several QDRs on the same stock number/item.

- It is easier to fix the item than to submit a report.

- In many cases, holding the defective item as an exhibit precludes replacement until disposition instructions are received.

- It is easier to make a phone call requesting assistance than to submit a report.

- Instructions for initiating and completing the form are unclear or difficult to understand. (Smith, 1985:8)

While this is not current knowledge, recent personal experience confirms that underreporting is still a problem, and the foregoing reasons are still valid -- further demonstrating that quality is a major concern.

Underreporting of defects tends to undermine the system and may mask possible problems at depot level. Additionally, as an after-the-fact measure, the QDR falls under W. Edwards Deming's category of "Quality by Inspection." According to Deming, "Companies that depend on mass inspection to guarantee quality will never improve quality. Inspections are too late, unreliable, and ineffective" (Walton, 1986:94).

Recognizing the lack of visible, shop-level quality measures, AFMC, in late 1989, asked the management consulting firm of Coopers and Lybrand (C&L) to study the C-141 line at Warner Robins Air Logistics Center (WR-ALC) using the Cost of Quality (COQ) method. The purpose of the study was to assess accurately the C-141 line, to give WR-ALC the chance to understand the methodology of data development and analysis, and to provide WR-ALC with the basis for improvement opportunities. In their report they concluded the following:

- Although much responsibility has been shifted to mechanics, the process is still heavily oriented toward inspection.

- The organization still operates primarily in a reactive mode

- There is insufficient data on in-process problems and delays.

- Schedule considerations are perceived as in conflict with, and more important than, quality issues.

- The timing and use of the production audit are questionable.

- The largest COQ is the additional cycle time required. (Coopers and Lybrand, 1990:20)

C&L's report highlighted important data that proved difficult to obtain, because WR-ALC was not currently collecting them. In particular, current data-collection systems do not track some common costs of quality, including scrap and rework. Depots have no direct way to measure repair versus scrap. Additionally, if an item needs to return upstream to be reworked, the current system does not track the extra time and labor expended in the loop (Glovka, 1992). As C&L says, "What you don't 'readily measure,' you don't get." (Coopers and Lybrand, 1990:12) If this information remains "invisible," the depots will be unable to improve the way they conduct business.

## Performance Measurement Systems

To confront the challenge of competition, depots must focus on maintenance processes and work to continually improve them (Hinneburg, 1992). A fundamental way to drive organizational performance and encourage change is through performance measurement systems. The purpose of measurement is to induce the organizational units to do what is good for

the organization as a whole. "Tell me how you measure me and I will tell you how I will behave" (Goldratt, 1990:13-17).

The Air Force and the rest of the DoD are now using a set of performance measures published by the Defense Depot Maintenance Council (DDMC) called Defense Depot Performance Measurement System (DDPMS) measures. The measures, developed by a task force composed of representatives from each service, the Joint Depot Maintenance Analysis Group, and the Defense Logistics Agency, are to be used "for decisions concerning depot investment, workload distribution, and continuous improvement initiatives." The key areas measured are effectiveness, efficiency, quality, productivity, innovation, capacity utilization, and cost performance. These areas should give a comprehensive depot profile (Defense Depot Maintenance Council, 1990:15-32).

In effect, DDPMS sets up competition among DoD maintenance depots using a system applicable to all defense depots. The DDMC charged the task force to "develop macro-level measures to be used for decisions concerning depot investment, workload distribution, and continuous improvement initiatives [emphasis added]" (Defense Depot Maintenance Council, 1990:ii). One of the questions the task force considered while developing the macro-level indicators concerned strategies for depot investment; another asked bluntly, "If work is to be reallocated, where should it go?"

(Defense Depot Maintenance Council, 1990:3). Not only, then, are depots competing with private firms, but they are also competing among themselves.

AFMC is also beginning to test measures based on the Theory of Constraints (TOC). These performance measures include the primary measures of throughput (T), inventory (I), and operating expense (OE). Derived measurements include net profit (NP $=$ T - OE), return on investment (ROI $=$ NP/I), inventory turns (IT $=$ T/I), and productivity (P $=$ T/OE). It is believed that these measures will drive depot performance in a direction consistent with achieving AFMC goals (AFLC/LGPP, 1992:3-5(a)).

## Problem Statement

If Air Force depots do not act to meet the challenge of competition, they may lose a significant share of the market from a product line (exchangeables in general) that has traditionally represented a substantial amount of depot work. Meeting that challenge will require performance measures that drive continuous improvement and induce the necessary performance. It is not known which approach -- DDPMS or TOC -- will produce better results.

## Overall Objective

The overall objective of this thesis is to determine which set of measures will better indicate performance to

allow the depots to be competitive along the three major competitive edges of quality, delivery, and cost.

## Investigative and Measurement Questions

The following investigative questions, along with associated measurement questions, were used in this study.

### Investigative Question #1:

What comprises competitiveness in the depot maintenance environment?

#### Associated Measurement Questions:

1. On which key areas of operations do private, for-profit firms concentrate to gain a competitive edge?

2. Of these, which apply to Air Force depots?

### Investigative Question #2:

How do the DDPMS and TOC measurements relate to each other?

#### Associated Measurement Questions:

3. What are the basic philosophies and underlying assumptions of each system?

4. How do the systems differ?

5. How are the systems similar?

<u>Investigative Question #3:</u>

Do DDPMS measures provide proper information to meet objectives whereby depot management can improve processes to compete on quality, delivery, and cost?

<u>Associated Measurement Questions:</u>

6.   To what extent do key areas of the DDPMS measures correspond to the three competitive edges?

7.   To what extent do the data collected by the DDPMS reflect improvement in the three competitive edges?

<u>Investigative Question #4:</u>

To what extent do TOC measures provide information that depot management can use to improve processes to compete on quality, delivery, and cost?

<u>Associated Measurement Questions:</u>

8.   To what extent do TOC measures correspond to the three competitive edges?

9.   To what extent do the data collected under TOC reflect improvement in the three competitive edges?

<u>Investigative Question #5:</u>

Which set of measures is being used to drive depot performance and why?

## Scope

This thesis will focus on the current literature to answer the first five investigative questions. In addition, it will present a study of an ALC that is using both sets of measurements. This thesis will study a small number of units, asking questions about the two different measurement systems in order to determine which measurement system (DDPMS, TOC, a combination of both, or neither), is actually driving performance. By asking depot managers directly, we hope to discover which measurement system tells them what they need to know in order to remain competitive.

## Limitations

Time does not permit a full-scale experiment that would test a number of units over a prolonged duration on their use of DDPMS measures, and of TOC measures. It is hoped that this research will serve as the foundation for further studies along the same lines. Other constraints include the availability of data and the time on the part of organizations to participate in a more comprehensive test. At present, not all DDPMS data are available (because of collection problems). TOC data, which demands even more comprehensive data collection, is also largely unavailable. The Depot Maintenance Management Information System (DMMIS) program would provide useful data to rate both systems. However, DMMIS is not yet on line, and will not be operational in the near future (Hinneburg, 1992).

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## Assumptions

All units must, by regulation, report DDPMS data, regardless of whether they have adopted TOC measures. It is assumed that units that have not yet been exposed to TOC measures and the Theory of Constraints philosophy are driven to perform mainly by the DDPMS measures and that those units that have begun to use the TOC measures now subscribe to TOC as a management philosophy.

It is assumed that the goal of each depot is to survive. Further, it is presupposed that to meet that goal they will strive to compete successfully on the bases of quality, delivery, and cost.

## Structure

The remainder of this thesis will seek to answer the investigative questions. The literature review in Chapter II will describe the current state of development in performance measurement and areas of competition. Next, Chapter III will establish and justify the research method of this thesis. Then, Chapter IV will analyze the available data and answer the research questions. Finally, Chapter V will discuss the findings of the research, present conclusions, and offer suggestions for the future, all based on the analyses of the literature review and the collected data.

## II. Literature Review

### Introduction

Air Force depot managers who wish to compete success-
fully may learn much from the current literature dealing
with competition in the private sector. In this chapter, we
will review the current thinking on competitiveness, empha-
sizing the three major factors of competitiveness: quality,
cost, and delivery. We will then discuss performance meas-
urements as a means to influence desired behavior to achieve
goals. Next, we summarize and assess the two performance
measurement systems currently in use in AFMC. Finally, we
will evaluate the body of collected literature with respect
to our research questions:

   1. On which key areas of operations do private, for-
profit firms concentrate to gain a competitive edge?

   2. Of these, which apply to Air Force depots?

   3. What are the basic philosophies and underlying
assumptions of the Defense Depot Performance Measurement
System and the measurements based on the Theory of Con-
straints (TOC)?

   4. How do the systems differ?

   5. How are the systems similar?

### Competitiveness

If depot maintenance is becoming a competitive environ-
ment, then how should Air Force depots behave in order to

meet that competition? First, it is useful to understand what being competitive means. Put simply, it means "being able -- effectively and efficiently -- to supply products and services that are on demand at acceptable levels of price and quality" (Steingraber, 1987:758-759).

By what standards, then, are depots measured? As mentioned in Chapter I, for many years the depots had a captive market in depot-level repair. In such a monopolistic environment, the customer has difficulty determining a "fair" price or a "reasonable" delivery lead time (except in comparing promised versus actual times), because no competitor exists with which to correlate performance. On the other hand, the customer can rate the product's quality against published objective inspection guidelines. Therefore, the quality of the delivered product is essentially the only yardstick available for base-level customers to judge depot performance.

Previously, depot customers had no control over the cost of depot-level maintenance. However, under new funding initiatives (i.e., the Defense Business Operations Fund (DBOF)), cost will become a factor by which base-level customers will appraise depot performance. For example, in the case of the depot competition discussed in Chapter I, in which AF depots lost three of the five contracts, cost (i.e., price of the product) was the deciding criterion (Owens, 1991). Nonprofit governmental organizations, when

faced with a choice among various alternatives for contract work, will tend to select the contractor who meets the minimum qualifications for the workload at the lowest price. Cost has become a highly important decision criterion.

However, it is anticipated that in the future, commanders will gain greater control over the sources of depot maintenance. They will become more typical customers, facing an array of choices with different prices, levels of quality, and delivery lead times. If the private sector is any indicator, they will judge any organization vying for depot maintenance contracts by its quality, cost, and delivery. These are the three competitive edges already recognized by depot management as vitally important (Kwolek, 1992:418) and by other researchers as the criteria by which customers decide whether or not to start or continue doing business with firms (Goldratt and Fox, 1986:36, Gilmour, 1977:145, Hayes and Wheelwright, 1984:40, Plossl, 1991:119, Blackburn, 1991:192-193).

## Factors of Competitiveness

These three dimensions of competitiveness are by no means unique to the Air Force depot system. Manufacturing firms worldwide struggle continually to achieve and preserve an advantage over their competitors. According to Umble and Srikanth,

> The basis of competition varies from one industry,
> company, or product to the next. But firms usual-
> ly achieve a competitive edge in one of three

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ways: (1) by having better quality products, (2) by offering superior customer service [of which delivery is a component], and (3) by being a low-cost producer. (Umble and Srikanth, 1990:36)

Organizations can gain a competitive edge by making better products (as perceived by the customer), offering lower prices, or providing faster response. Goldratt and Fox (1986) identify the competitive categories of product, price, and responsiveness. The customer can judge a product as "better" if it has superb quality and excellent engineering.[1] Price also has two aspects: higher margins and lower investment per unit. The company that has the highest margins -- or lowest cost -- enjoys greater pricing flexibility, so it can capture the market. Moreover, because of its lower investment per unit, it will have a lower break-even point, allowing for greater flexibility to compete. Finally, responsiveness can be further subdivided into two parts: due-date performance and shorter quoted lead time. The first deals with a firm's success in delivering a certain quantity of product by a certain due date; the second refers to the firm's ability to commit to earlier delivery dates than its competitors (Goldratt and Fox, 1986:36).

Cost, of course, is the most familiar competitive dimension. Besides cost, Hayes and Wheelwright cite quality and dependability as vital competitive edges. Firms achieve

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1. The term "superb quality" is analogous to *conformance quality*, while "excellent engineering" is another way of decribing *design quality*. (Chase and Aquilano, 1991:167-168)

a reputation for superior quality through high product reliability, good performance in a standard product, or producing a product with features not currently found in competing products. Dependability refers to how well a company delivers a product that works as advertised when the customer wants it (Hayes and Wheelwright, 1984:40).

George Plossl, a published expert in the field of corporate competition, cites several factors a firm should address in order to improve its competitive strength, most notably: (1) the ability to satisfy (not just "serve") their customers and (2) achieving cost leadership. The first factor involves a company's speed in responding to changes, its flexibility in meeting current actual demand by the judicious application of resources, and its times required for delivery. The second factor relates to not just reducing manufacturing costs, but eliminating them wherever possible, and reducing the cost of the product itself. Success in the second factor -- if achieved smartly through "improvements in the flows of materials and information" -- increases a firm's ability to further satisfy its customers with more on-time deliveries, greater flexibility in meeting customer requirements, and the ability to introduce new products (Plossl, 1991:118-121).

Competition requires that organizations understand the complete manufacturing process (Umble and Srikanth, 1990:3). The way they can gain and maintain competitive excellence

involves management's view of the manufacturing function, its role, and how that ought to be carried out. Therefore, restoring an organization's competitive edge demands a basic change in philosophy, perspective, and approach (Wheel-wright, 1985:27).

Management, then, needs to be able to measure its organization's performance in order to ensure it is meeting its competition successfully. According to Wisner and Fawcett, world-class manufacturers develop performance measures that create and sustain customer service. These measures include "quality," "cost," and "dependability" (a facet of which is delivery). These measures are critical to the continued success of the firm and form the foundation for improving its competitive position (Wisner and Fawcett, 1991:6).

Many sources agree that quality, cost, and customer service (delivery) constitute the three major dimensions by which an organization can increase its competitive edge. In the depot environment, the same is true. Kwolek's research showed that quality, delivery, and cost were the top three competitive edges that depot managers considered important. She surveyed six depot maintenance organizations, asking them to order the competitive edges by objectives and by performance criteria. Figure 2.1 shows that in both cases, managers ranked quality, delivery, and cost in the top three (Kwolek, 1992:418).

| Rank Order of Competitive Edges on the Basis of Unit Objectives | | | | | | |
|---|---|---|---|---|---|---|
| Rank Order | C-130 | C-141 | F-4 | F-16 | F-111 | A-10 |
| 1 | Quality | Quality | Quality | Quality | Quality | Quality |
| 2 | Delivery | Delivery | Delivery | Delivery | Cost | Cost |
| 3 | Cost | Cost | Cost | Cost | Delivery | Delivery |
| 4 | Lead Time | Lead Time | Flexibility | Lead Time | Lead Time | Innovation |
| 5 | Flexibility | Innovation | Lead Time | Innovation | Flexibility | Lead Time |
| 6 | Innovation | Flexibility | Innovation | Flexibility | Innovation | Flexibility |

| Rank Order of Competitive Edges on the Basis of Performance Criteria | | | | | | |
|---|---|---|---|---|---|---|
| Rank Order | C-130 | C-141 | F-4 | F-16 | F-111 | A-10 |
| 1 | Quality | Quality | Quality | Quality | Quality | Cost |
| 2 | Delivery | Cost | Cost | Cost | Cost | Quality |
| 3 | Cost | Delivery | Delivery | Delivery | Delivery | Delivery |
| 4 | Lead Time | Lead Time | Lead Time | Lead Time | Lead Time | Flexibility |
| 5 | Flexibility | Innovation | Innovation | Flexibility | Innovation | Innovation |
| 6 | Innovation | Flexibility | Flexibility | Innovation | Flexibility | Lead Time |

**Figure 2.1: Cross-Case Comparison of Competitive Rank Order by Unit Objectives and Performance Criteria**
(Adapted from Kwolek, 1992:418)

We conclude from the literature that quality, delivery, and cost are the key areas of operations private firms focus on to gain a competitive edge, thereby answering our first research question.

From Kwolek's research, we see that the same three key areas are important to depot managers. Although this is the only available source investigating competitive factors in Air Force depots, it is nonetheless recent, relevant, and complete. Therefore, Kwolek's study offers strong, compelling evidence that quality, delivery, and cost are the primary areas in which Air Force depots can gain a competitive advantage, thus answering our second research question.

Some sources cited flexibility and/or innovation as ways that firms may gain advantage over the competition (Plossl, 1991:119). In fact, Michael Porter, a widely published and well-respected authority on competitiveness, states that innovation (or technological change) is one of the chief ways in which firms may compete. Innovation can enhance a firm's competitive position, while eroding a competitor's advantage in the marketplace (Porter, 1985(a):164). However, it is our contention that although it is important for organizations to pursue improvements in flexibility and innovation, they are not competitive edges themselves. They are a valuable _means_ that firms may employ to increase their competitiveness with respect to quality,

cost, and delivery.  For example, a firm can innovate and alter its processes to improve quality or reduce costs.

Having identified the three competitive edges, we believe it is appropriate to take a closer look at them, individually, and discern ways in which they may be measured.

## Quality

Shetty and Buehler define quality as "doing it right the first time."  A firm that does this will reduce costs and thus increase productivity.  Quality also affects a firm's sales and market share.  A reputation for quality guarantees success.  Therefore, it is a major factor in any organization's competitiveness.  In simple terms, quality is a key attribute that customers use to evaluate products or services.  We should define quality from the customer's perspective and compare a firm's products and services to the products or services offered by competitors (Shetty and Buehler, 1988(b):5).

Quality is more than finding items that do not meet design specifications and throwing them away.  To achieve true quality improvements, firms must control the process, not the product (Chase and Aquilano, 1991:209).  When firms focus on "inspecting in" quality, it contributes to workers' shifting the responsibility of a job done correctly to the inspector who must weed out the lemons.  This attitude inhibits the quality awareness that is crucial if firms

truly desire to eliminate defects and rework (Blackburn, 1991:138).

As Julie Holtry, Hewlett Packard's (1988) Corporate Quality Marketing and Communications Manager, puts it:

> The fact is that competition is demanding much more from us -- and quality is becoming a key differentiator, and a strategic issue which must be used to competitive advantage.... [Managers] must create a revitalized environment where a shared vision becomes the driving force for quality improvement and teamwork is used to effectively execute these strategic visions. (Holtry, 1988:444)

The father of the quality movement, W. Edwards Deming, insists that competitiveness on quality cannot be obtained through inspection methods, but must occur through a concerted effort to change the way the organization perceives quality. Deming insists that an organization must have universal acceptance and participation in the quest for quality (Walton, 1986:34). Many companies have had major successes through a company-wide effort, working together to create a culture that promotes total quality improvement (Byrne and Markham, 1991:2).

David McCamus, chairman of Xerox Canada, stresses the need to determine the costs of quality, which he separates into three crucial areas: non-conformance, conformance, and lost opportunity. Non-conformance costs occur when the customer's requirements are not fulfilled, or when the firm has to rework things because of mistakes. These costs can run as high as 20 percent of a company's revenue. Confor-

mance represents the cost of "doing it right the first time," which may include employee training costs, process improvement costs, etc. McCamus says that these costs are almost always significantly lower than non-conformance costs. Lastly, he contends that lost opportunity is difficult to quantify, but considerable nonetheless. He claims that, even if customers do not complain to the firm, they will usually tell friends and colleagues about the company's errors. Knowing this fact, McCamus says, "We can see that not satisfying customers creates very high costs of lost opportunities" (McCamus, 1991:9).

Reichheld and Sasser measure these lost opportunities through defection analysis, which measures the cost of losing a customer to the competition. According to them, the average firm can double its growth rate simply by cutting its defections in half. Unfortunately, even though modern cost accounting methods do not reveal this cost relationship the authors' analysis clearly shows that firms that maintain high quality and customer service profit greatly. This is because customers are more profitable over time, for the following reasons:

1. Established customers tend to increase their number of purchases and maintain higher balances.

2. Operating costs over the long term decrease, translating into higher profits.

3. Customers refer others to the firm (Reichheld and Sasser, 1990:106-108).

Ensuring a high degree of quality, then, is important as a means of favorably differentiating an organization from its competitors. A strong focus on quality should lead not merely to a decrease in defects, but ultimately to a change in the organization's culture, whereby people no longer tolerate substandard behavior and actually welcome continual process improvements.

## Delivery

In the current literature concerning competitiveness, delivery capabilities are frequently subsumed under the larger heading of "customer service." Usually, end users judge a firm's customer service by two aspects: due-date performance and quoted lead time performance. If a company cannot deliver its products on time, it will lose market share, regardless of the products' level of quality. Conversely, a firm that can make good on its promise of short lead times will gain a substantial advantage over its competitors who meet quoted delivery dates, but with longer lead times (Umble and Srikanth, 1990:36).

Porter focuses on the entire logistics chain with the aim of creating a more efficient logistics system and providing a more responsive after-sale support function. A firm that wants to gain a competitive edge can challenge the

industry leader through improving its product support and physical distribution (Porter, 1985(a):520-521).

Competition on delivery lead times has been increasing in recent years. In a wide variety of industries, shorter lead times can represent the decisive edge. In fact, some companies have been able to charge premium prices because no other firm can match their quick response to customer orders (Goldratt and Fox, 1986:62-63).

Plossl lists several objectives to achieve full customer satisfaction, which include producing what customers need when they need it, and then delivering it to their desired location. Historically, customers tried to compensate for suppliers' uncertain quality and poor delivery by padding orders, asking for greater quantities than they really required at times far sooner than needed. Thus, a supplier that meets delivery schedules with high-quality products can save customers money and grief, while effectively edging out the competition (Plossl, 1991:41-42).

Manufacturers are developing quick order response capability as a key to achieving a competitive advantage. Effective logistics practices can help domestic manufacturing and distribution operations deliver high-quality goods on time with shorter lead times and faster order fills. If a firm can consistently create a consistently good product, an outstanding logistics system can add real value to the company (Ernst and Whinney, 1987:154-155).

Delivery is an important aspect of competitiveness. Customers appreciate a firm's ability to meet due dates and commit to shorter quoted lead times. Delivery as a dimension of competition is important in the Air Force, as well. In fact, each depot's effectiveness (under the DDPMS) is measured partly on its ability to produce scheduled units and deliver them on time (Defense Depot Maintenance Council, 1990:15-16). AFMC felt so strongly about on-time deliveries that it declared a "War on Delinquencies" in 1987. In two years the on-time delivery rate increased from 65 percent to 79 percent (HQ AFLC/XPP, 1991:40).

The preponderance of the literature, as well as the importance DoD places on this competitive edge, lead us to conclude that delivery (whether considered as part of the broader topic of customer service or as a competitive edge by itself) is an essential factor of competitiveness that organizations should strive to improve.

## Cost

A company can differentiate itself in the marketplace by offering prices as low as or lower than the competition's. A low-cost position will yield greater-than-average returns despite the presence of strong competitive forces. A firm that reduces its costs can defend itself in the marketplace against its rivals. Lower costs can be passed on through lower prices or used to gain higher margins, which the company can reinvest in new equipment and moderni-

zation, further enhancing its cost leadership position (Porter, 1985(b):36).

However, a firm must be careful that it does not undermine the other features by which it has differentiated itself in the market. In other words, if a company cuts costs to be the "cost leader" in a particular market, it must take care that doing so will not abandon its "sources of uniqueness to the buyer" (Porter, 1985(b):117-118).

Traditionally, firms have tried to compete with their rivals by cutting costs and lowering prices. Reducing cost -- both internal costs and prices that companies charge -- is important but should not be the sole reason for any business decision. "Companies that pursue change by focusing on cutting costs are only asking for trouble" (Blaxill and Hout, 1991:193).

When reducing costs, firms must reduce total cost. That is, if firms cut costs in function, the impact will be felt elsewhere in the firm. If management does not take an integrative approach, its attempts to reduce specific costs "may be less than optimal for the system as a whole, leading to greater total costs" (Stock and Lambert, 1987:568).

Paradoxically, the money and effort spent on creating a quality culture within an organization can contribute to the overall reduction of cost. Finding and tracking defective work, and eventually scrapping or reworking items usually costs much more than doing the job correctly in the first

place. Crosby claims that firms waste more money producing inferior goods (which are tolerated within quotas, e.g., acceptable quality levels) than they would if they adopted a comprehensive policy of zero defects (Crosby, 1979:15).

Firms should identify cost as a major component of their overall efforts to improve their competitive position. They must effectively manage all parts of their operations if they truly want to become a low-cost producer in the market. To compete on cost, companies must be able to keep operating expenses as low as possible and stop buying unnecessary equipment (Umble and Srikanth, 1990:45).

This discussion on cost underscores the importance of balancing the firm's competitive factors. An overemphasis on any one factor (typically, cost) will likely have a deleterious effect on the rest. In "The Balanced Scorecard -- Measures That Drive Performance," Kaplan and Norton state:

> As managers and academic researchers have tried to remedy the inadequacies of current performance measurement systems, some have focused on making financial measures [i.e., cost] more relevant. Others have said, "Forget the financial measures. Improve operational measures like cycle time and defect rates; the financial results will follow." But managers should not have to choose between financial and operational measures. In observing and working with many companies, we have found that senior executives do not rely on one set of measures to the exclusion of the other. They realize that no single measure can provide a clear performance target or focus attention on the critical areas of the business. Managers want a balanced presentation of both financial and operational measures. (Kaplan and Norton, 1992:71)

In and of themselves, the three factors of competitiveness -- quality, delivery, and cost -- are important. The question remains as to how an organization can exploit and maximize performance with respect to these factors. That is where performance measurement comes in.

## Performance Measures

An organization develops measures in order to encourage behavior that will move the entire organization closer to meeting its stated goal. If a measurement system is illogical or is incongruous with the objectives of the organization, we should not be surprised at the illogical behavior that follows (Goldratt, 1990:28). We further need to be aware that measurement systems that emphasize maximizing local optima will usually do so at the expense of the entire system. Good measures, then, will encompass the entire system and drive the organization to achieve its goal (Goldratt and Fox, 1986:60).

Firms in the United States have begun to recognize that their current measurement systems are inadequate to the task. Recognizing the discontinuity between shop-floor measures and company financial performance, they are seeking to link the manufacturing performance measures at all organizational levels. This linkage will ensure constancy of purpose among organizational levels and point to cause-and-effect relationships so all employees can attack problems that cause poor performance, while continuing practices that

cause good performance. Measures should help improve the organization's critical success factors -- which include quality, customer service, and cost -- and linking them to low level measures that workers on the "front lines" can identify with (Beishel and Smith, 1991:25-29).

When changing measures, corporate leaders must keep in mind several things. First, performance measures guide and enhance management action; therefore, they should derive from strategy. Without derivation from strategy, measurements will measure erroneous or obsolete things. Second, performance measures are hierarchical as well as integrated across business functions. Therefore, measures should link together and become more specific moving down the organizational chain. .Third, the measures must support a company's multidimensional environment. In other words, they must reflect the goals of the firm. Lastly, measures must be based on a thorough understanding of cost relationships and behavior. This way, the firm will be able to trace costs all the way to the customer. After all, providing goods or services at minimum cost to insure profit is the ultimate goal of most companies (Keegan, Eiler, and Jones, 1989:45-50).

Carl Thor states that many large organizations have developed organizational management measurement systems, but have not made use of the obvious implications of having an organization-wide measure of productivity. In other words, performance measures are used, but not at the most important

places. Thor recognizes the need for measures at the lowest level of the organization. Further, each level should have its own measurement of performance that matches with, or supports the overall organizational measurement. Without these, he contends that firms cannot attain goals and that company measurements will not truly represent goal attainment (Thor, 1991:17-19).

## Defense Depot Performance Measurement System (DDPMS)

The DoD's attempt at developing a comprehensive set of measurements that drives depots toward attaining goals is the DDPMS. Developed by the Defense Depot Maintenance Council (DDMC), the DDPMS consists of a set of seven indicators by which all depots can be measured. The measurement system will provide indicators of depot performance in efficiency, effectiveness, quality, productivity, innovation, capacity utilization, and cost performance (DDMC, 1990:ii). Figure 2.2 presents a brief index of measures that depots must account for quarterly.

**Effectiveness** is derived by dividing the actual output of a depot by its expected output. The desired ratio is 1. A ratio of less than one indicates late completion. On the other hand, a ratio greater than one is not permitted, because of the way the indicator was designed. In fact, the DDMC believes that early delivery is not desirable; first, because pushing an item for early completion can cause other

## Performance Measurement System

*Index of Measures*

**Performance Measurement Composite**

**Effectiveness:**
> Schedule Conformance

*Effectiveness is the degree to which a depot does what it sets out to do during a specified period.*

**Efficiency:**
> Direct Labor Utilization
> Direct Material Utilization

*Efficiency is the alignment of planned to actual utilization.*

**Quality:**
> Cost of Quality
> Nonconformance/Conformance Ratio

*The cost of preventing errors, of inspecting for errors after production, of internal failures to conform, and of failures of products and services once they reach customers.*

**Capacity Utilization:**
> Peacetime Utilization Index

*An indicator, expressed as a percentage of the degree of alignment of workload to the designed capacity of a depot.*

**Productivity:**
> Productivity Index

*The ratio of the value of output (finished products) to the cost of input (labor, capital, material, etc.)*

**Cost Performance:**
> Cost Performance Index

*The amount of revenue earned compared to the cost of goods sold. It shows how well a depot is executing its programs in relation to its budget.*

**Innovation:**
> Innovation Narrative

*A qualitative indicator in the form of a short narrative report from the depot summarizing the steps taken in the last quarter to maintain progress in innovation.*

**Figure 2.2: Index of DDPMS (AFLC/ LGPP, 1991(a):6)**

products to run late; and second, because it may "suggest that a depot has excess capacity" (DDMC, 1990:17).

This line of reasoning runs counter to the Theory of Constraints (TOC), which considers shorter quoted lead times a significant competitive advantage. While the DDPMS drives managers to adhere only to the established schedule, TOC recognizes that if a firm can negotiate a shorter quoted lead time with its customer, and then actually deliver, it can differentiate itself through superior customer service (responsiveness). Goldratt writes that competitive edges like shorter quoted lead times might be thought of as "our future output" (Goldratt and Fox, 1986:36).

The second key area, efficiency, contains three measurement indicators, direct material, direct labor, and direct material used. Direct material is the "material that is directly assignable and chargeable to a specific job." The DDMC calculates this measure by dividing the value (dollars) of the direct material the depot planned to use by the value of the direct material used during the reporting period. Direct labor is "labor that is directly assignable and chargeable to a specific job." It is calculated by dividing the number of direct hours earned (derived through accepted engineered standards for each job) by the number of direct hours used. The goal is to achieve a ratio of one, which provides evidence of successful planning and scheduling. The DDPMS strongly emphasizes depot planning func-

tions; depots that do the things they intend to do. The DDMC remarks, "One improvement that may come from using this measure may be to stop the practice of planning based solely on how work was done before, and focus on how work can be done more efficiently" (DDMC, 1990:19).

The third key area is quality. The DDPMS measures quality in two ways, the cost of quality and the non-conformance/conformance ratio. Cost of quality represents all the costs that arise because of internal failure, external failure, prevention, and appraisal of a depot's products and services (AFLC/LGPP, 1991(b):9-11). Once again, the measure is expressed as a ratio. The COQ index is calculated by dividing the cost of quality by the total cost of the product. The measure is intended as a guide to drive improvement. The DDMC contends that as depots move from traditional management to total quality management (TQM), the costs of internal failures, external failures, and appraisal will all decrease as managers place greater attention on and investment into prevention.

The second measure of quality is the non-conformance/conformance ratio. Although it is called the nonconformance/conformance ratio, it actually divides the cost of conformance to requirements (including appraisal and prevention activities) by the cost of not conforming to requirements (internal and external activities and costs). The goal is to drive the ratio higher, thereby emphasizing

the need to increase attention on prevention rather than fixing things afterward (DDMC, 1990:20-24).

The next key area, productivity, is "the ratio of output (finished products) to the cost of input (labor, capital, material etc.)." The increase in the ratio is considered good, because it means that costs are decreasing. The composite index is a result of a five-step process that computes the sum of the individual inflated base period values and divides that figure by the sum of individual current period costs (DDMC, 1990:26-28). It is questionable whether such a highly aggregated ratio gives managers any sense of what they should do to increase productivity.

Innovation is a qualitative indicator. The DDPMS requires a short narrative in which depots must describe the steps they are taking to maintain progress in innovation. The report includes technical innovations and managerial innovations. It is hoped that through these qualitative narratives, a depot can gain a reputation for innovation, which will increase its competitiveness. Policy makers will take a depot's history of innovative actions into account when assigning workload, especially when making investment decisions (such as where to put new weapon systems) (DDMC, 1990:29-30).

Capacity utilization, the next key area, is defined by the peacetime utilization index, which is calculated by dividing funded workload by the capacity index. The capaci-

ty index equals the number of work positions times the depot's availability factor (set in AFMC at 0.95) times quarterly productive hours (AFLC/LGPP, 1991(b)). The measure is intended to be used for future workload planning, but the index is so highly aggregated that it is impossible to tell what kind of workload is available at a depot, only that some ability exists to take on some undefined workload.

The last key area, cost performance, is a measure of performance, but the DDMC admits that inter-depot comparisons are tricky. One reason is that regional labor costs differ. Another is that Services define "cost" in different ways that resist meaningful comparison. Finally, workloads among depots vary so greatly that cost comparisons are impossible. To get around this problem, the DDMC measure cost as a ratio between revenue earned and cost of goods sold. The ratio should ideally be one, reflecting good planning on the part of depot managers.

The key areas that the DDPMS measures are supposed to work in the following way. A depot that has a high effectiveness rating "does the right things on time." If it is efficient, it "does things the right way with the right amount of resources." And if its quality measures are favorable, it "successfully manages the costs of quality." Finally, if the depot is "within the limits of its capability," then its capacity utilization measure will be favorable. If all the foregoing statements are true, then the

depot will very likely be _productive_. Furthermore, if it also makes significant contributions to _innovation_, it will most likely show _cost performance_ to achieve _excellence_, _survival_, and -- finally -- _customer satisfaction_, which is the ultimate measure of performance and is reflected in the seven measurement areas (DDMC, 1990:14).

One chief goal of the DDMC in creating the DDPMS was to establish a measurement system that would allow inter-depot comparisons. Because depots across the different Services have markedly different workloads, accounting systems, philosophies of management, and data collection capabilities, the DDPMS offers measures that are so highly aggregated and homogenized that they have little applicability to individual depots, let alone to depots across the various Services (Swartz, 1992).

## Theory of Constraints

The Theory of Constraints (TOC) is a management philosophy that concentrates on balancing flow rather than capacity. The latter focus has been common throughout the manufacturing milieu. TOC, also known as "synchronized manufacturing," recognizes that balancing the capacity can lead to wasted effort and lost opportunities. TOC emphasizes the entire system and describes the manufacturing system as a series of dependent events that are subject to statistical fluctuation (Chase and Aquilano, 1990:797).

Rather than schedule backwards from market demand and apportion capacity equally among all subsystems, Dr. Eliyahu Goldratt, the chief proponent of TOC, believes firms should discover what is hindering their systems from producing more and focus their attention on that weakest link, which he calls the "constraint." Goldratt says that organizations can have only one constraint per independent chain of processes (Goldratt, 1990:53).

The constraint can be anything from a slow machine to a saturated market. The system cannot produce at a greater capacity than the constraint. If any other subsystem within the chain produces at a capacity greater than the constraint, then that effort is wasted (e.g., becomes work-in-process inventory that builds up behind the constraint). In addition, since the capacity of the constraint is equal to the capacity of the system, any lost time on the constraint is lost time for the entire system (Goldratt and Cox, 1986:157).

TOC exploits constraints within systems to create a process of ongoing improvement. Goldratt's method to establish this process is as follows:

> 1. Identify the System's Constraint(s)
> 2. Decide How to Exploit the System's Constraint(s)
> 3. Subordinate Everything Else to the Above Decision
> 4. Elevate the System's Constraint(s)
> 5. If, in the Previous Steps, a Constraint Has Been Broken, Go Back to Step One, but Do Not Allow Inertia to Cause [or Become] a System's Constraint. (Goldratt, 1990:59-63)

In order to exploit a system constraint, the rest of the system needs to operate at a pace less than or equal to the pace of the constraint. In other words, the constraint is the system's <u>drum</u> that sets the pace. Non-constraints preceding the constraint need to produce inventory to keep the constraint operating (an hour lost on the constraint is an hour lost to the system). This location, in which inventory is allowed to accumulate to protect against idle time on the constraint, is called a <u>buffer</u>. Finally, non-constraints need to know the pace of the system. The communication apparatus between the constraint and the rest of the system is called a <u>rope</u>. "In actuality, the <u>rope</u> is a methodology to ensure the required synchronization . . . without having to actively control each individual resource" (Umble and Srikanth, 1990:136-139).

Goldratt says that in most firms the constraints are not physical constraints but arise from policy decisions (Goldratt, 1990:62-63). In other words, organizations have erected their own (unnecessary) barriers to impede the attainment of their goals. According to Goldratt, the underlying goal of a for-profit firm is "to make money in the present as well as in the future" (Goldratt and Fox, 1986:19). He believes that a powerful constraint on firms is the measuring and reporting systems that nearly all of them use, which are based on cost accounting. A fundamental reason that managers continually make poor decisions is that

they base these decisions on cost accounting, which promotes short-sightedness and sub-optimization. Johnson and Kaplan claim that cost accounting has become irrelevant, if not downright destructive. It exists, apparently, merely to give senior managers periodic, usually monthly, (worthless) financial reports.

> Typical 1980s cost accounting systems are helpful neither for product costing nor for operational cost control; they do no provide information useful for cost management. (Johnson and Kaplan, 1987:195)

In place of cost accounting, TOC offers a new measurement system based on three global measures: throughput, inventory, and operating expense. These are defined as follows: "Throughput -- The rate at which the system generates money through sales. Inventory -- All the money the system invests in purchasing things the system intends to sell. Operating Expense -- All the money the system spends turning inventory into throughput" (Goldratt and Fox, 1986:29).

AFMC determines the global measures (which it calls "Primary Measures") thus:

---

Throughput (T) = Revenue - Direct Material Consumed
Inventory (I) = Undepreciated Portion of Capital Assets +
      Unconsumed Direct Material + Reparable Assets
Operating Expense (OE) = Labor + Utilities + Depreciation +
      Supplies + Base Services + Contractor Support

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**Figure 2.3: TOC Primary Measures**
**(First Described by Goldratt) (AFLC/ LGPP, 1992(a):3)**

In addition, they suggest <u>Derived Measures</u> based on the Primary Measures.

---

Net Profit (NP) = T - OE
Return on Investment (ROI) = NP/I
Inventory Turns (IT) = T/I
Productivity (P) = T/OE
Throughput*Dollar*Days (TDD) = Value of the Order * Number of Days Late
Inventory*Dollar*Days (IDD) = Sum of the Daily Value of Inventory

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**Figure 2.4: TOC Derived Measures
(Based on Work by Goldratt) (AFLC/LGPP, 1992(a):3-4)**

The aim of using TOC-based measures in the AFMC depot system is to make the goals of AFMC and the means to achieve those goals clear to everyone in AFMC. The measures should be used from the shop floor to the high command echelons. In addition, AFMC has started an education program to train personnel in the principles of the Theory of Constraints to insure understanding and acceptance (AFLC/LGPP, 1992(a):10).

In conclusion, the Theory of Constraints is a system that directs organizations to find what is stopping them from attaining their ultimate goal, whatever that may for the particular organization. Measurements based on TOC link the shop floor to upper management and provide a more realistic snapshot of organizational performance. Moreover, TOC breaks down the barriers between subunits within the organization so that all subunits strive to improve the organization as a whole, not simply to increase their own local performance.

## Assessment

Our review of the literature clearly shows that the two measurement systems (DDPMS and TOC-based) are greatly different. DDPMS measures are efficiency-related and cost-based. In addition, since the DDMC wanted to create a system that would apply to all Service depots, many of the measures are highly aggregated and represent ratios and indices, comparing what depots planned to do versus what they actually did. The TOC measures, however, are concerned with discovering and exploiting an organization's constraints. TOC measures performance with quantifiable data (e.g., units produced, delivered, or stored as inventory, and dollar amounts of T, I, and OE). Thus, we contend that the answer to investigative question #2 ("How do the DDPMS and TOC measurements relate to each other?") is that the two measurement systems are completely different. They are similar in that they both measure depot performance, but each system measures it in its own unique way.

## Summary

In this chapter, we discussed competitiveness and what Air Force depots should do to meet the competition for workload that they soon will face. We presented the most prominent factors of competitiveness, which the current relevant literature identified as quality, delivery, and cost. Then, we elaborated on each of the three major factors of competitiveness. Finally, we examined the two

performance measurement systems (DDPMS and TOC-based) that Air Force depots are currently using.

The literature review has answered the first two investigative questions. The answer to Investigative Question #1 (What comprises competitiveness in the depot maintenance environment?) is that three main factors -- quality, delivery, and cost -- are the chief ways in which firms increase their competitive advantage in the marketplace. The research also indicated that these competitive edges also apply to Air Force depots. The answer to Investigative Question #2 (How do the DDPMS and TOC measurements relate to each other) is that the two systems are markedly different. DDPMS measures are cost- and efficiency-based, while the TOC measures are based on the idea of finding the organization's constraints and exploiting them to gain advantage.

Chapter III will address the methodology used to assess the two measurement systems and to answer the remaining research objectives (Investigative Questions 3 through 5).

# III. Methodology

## Introduction

This chapter describes the basic methodology employed in order to answer the investigative questions posed in Chapter I. This methodology followed a two-phase approach. Phase I, the literature review, sought to answer investigative questions #1 and #2. Phase II of the methodology consisted of interviews with depot managers to discover whether they understand the measures and to determine how they use them in their day-to-day work.

Applying nonparametric statistical tests to the depot managers' inputs provided the quantitative basis for answering associated measurement questions 6 and 8 (under investigative questions #3 and #4), which addressed the correspondence of the measurement systems to the three competitive edges of quality, delivery, and cost. Next, content analysis was used to determine the extent to which the measurement systems provided data to help managers improve performance with respect to these edges (see associated measurement questions 7 and 9). Content analysis also served as the basis for the evaluation of investigative question #5 (Which set of measures is being used to drive depot performance and why?).

<u>Phase I</u>

The purpose of Phase I was to answer investigative questions #1 and #2. This phase involved a thorough review of the relevant literature concerning competitiveness, performance measurement, the Defense Depot Performance Measurement System (DDPMS), and the Theory of Constraints (TOC). This in-depth review was a necessary step in forming the foundation for the rest of the study.

The detailed survey of the literature revealed that quality, delivery, and cost were the three principal competitive edges comprising competitiveness in private industry. The preponderance of the relevant current literature clearly identified these three factors as crucial to becoming and remaining competitive. While some authors mentioned other possible factors (e.g., innovation and flexibility), nearly every source agreed that cost, delivery, and quality were of primary importance. Additionally, Kwolek's work suggests that these three factors are equally crucial in the depot maintenance environment (Kwolek, 1992:454-456).

The literature review also answered investigative question #2. The literature showed that DDPMS and TOC both measure depot performance, but each system measures it in its own unique way. Further, DDPMS uses highly aggregated indices (ratios) while TOC measures performance with tangible quantities, like dollar amounts and units produced, delivered, or stored as inventory. The review led to the con-

clusion that the two measurement systems are completely different in how they measure depot performance.

## Phase II

The Survey of Depot Managers. Based on consultation with AFMC officials, Warner Robins Air Logistics Center (WR-ALC) was chosen as the population for the study. WR-ALC is the first ALC to attempt full-scale implementation of TOC measures. Since all ALCs must collect data for DDPMS, WR-ALC was the ideal candidate for a depot population using both sets of measurements. Thus, it was assumed that managers at Warner Robins should be familiar with both measurement systems, and data for both systems should be available.

The area of exchangeable repair was selected as the focus of the study, since this will soon be an area in which ALCs will have to compete against private firms for work load (Gen Hinneburg, 1992). The two directorates (hereafter referred to as Directorate 1 and Directorate 2, to preserve their anonymity) chosen for the study were currently involved with the repair of exchangeables as well as the implementation of TOC measures. The particular divisions (referred to as Divisions 1A and 2A) under the directorates were chosen because of their TOC training, their willingness to participate in the study, and the broad diversity of work performed within the division. The division-level managers picked three of their branches (referred to as Branches 1A1,

1A2, 1A3, 2A1, 2A2, and 2A3) for the interviews. The branches under Division 1A represent three from a population of ten branches, while those under Division 1B represent three from a population of four branches.

The two directorate managers, two division managers, and six branch managers comprised the ten managers who were our sample. So the managers would feel free to express themselves openly, the names of individuals and organizations in this study were omitted. In addition, the true identities of the people and their organizations were irrelevant to the research; therefore, they will remain anonymous.

In order to compare DDPMS to the TOC-based measures, it was useful to construct a matrix for each competitive edge (see Figures 3.1 through 3.3). The matrices represent the evaluations each manager made between a measure and a competitive edge. An interview (see Appendix A) was conducted with the sample group of ten depot managers. Within each cell of the matrix, a yes or no ("Y" or "N") response was entered, according to the interviewees' responses.

Test Method for Phase II. Because of the relatively small sample size, this study used nonparametric statistics, first to determine whether a difference existed between the two systems, and then to determine whether one was better than the other (in terms of usefulness with respect to each

**Competitive Edge: Quality**

| | Directorate 1 | | | | | Directorate 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 1A | 1A1 | 1A2 | 1A3 | 2 | 2A | 2A1 | 2A2 | 2A3 |
| ▲ DDPMS Measures: | | | | | | | | | | |
| Schedule Conformance | | | | | | | | | | |
| Direct Labor Utilization | | | | | | | | | | |
| Cost of Quality | | | | | | | | | | |
| Peacetime Utilization Index | | | | | | | | | | |
| Productivity Index | | | | | | | | | | |
| Cost Performance Index | | | | | | | | | | |
| Innovation | | | | | | | | | | |
| ▲ TOC Measures: | | | | | | | | | | |
| Throughput (T) | | | | | | | | | | |
| Inventory (I) | | | | | | | | | | |
| Operating Expense (OE) | | | | | | | | | | |
| T Dollar Days | | | | | | | | | | |
| I Dollar Days | | | | | | | | | | |
| I Turnover | | | | | | | | | | |
| Net Profit | | | | | | | | | | |

Figure 3.1: Quality vs. Measurement System Matrix

**Competitive Edge: Delivery**

| | Directorate 1 | | | | | Directorate 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 1A | 1A1 | 1A2 | 1A3 | 2 | 2A | 2A1 | 2A2 | 2A3 |
| ▶ DDPMS Measures: | | | | | | | | | | |
| Schedule Conformance | | | | | | | | | | |
| Direct Labor Utilization | | | | | | | | | | |
| Cost of Quality | | | | | | | | | | |
| Peacetime Utilization Index | | | | | | | | | | |
| Productivity Index | | | | | | | | | | |
| Cost Performance Index | | | | | | | | | | |
| Innovation | | | | | | | | | | |
| ▶ TOC Measures: | | | | | | | | | | |
| Throughput (T) | | | | | | | | | | |
| Inventory (I) | | | | | | | | | | |
| Operating Expense (OE) | | | | | | | | | | |
| T Dollar Days | | | | | | | | | | |
| I Dollar Days | | | | | | | | | | |
| I Turnover | | | | | | | | | | |
| Net Profit | | | | | | | | | | |

**Figure 3.2: Delivery vs. Measurement System Matrix**

| | | Competitive Edge: Cost | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Directorate 1 | | | | | | Directorate 2 | | | | | | | |
| | 1 | 1A | 1A1 | 1A2 | 1A3 | 2 | 2A | 2A1 | 2A2 | 2A3 | | | | | |
| ▲ DPPMS Measures: | | | | | | | | | | | | | | | |
| Schedule Conformance | | | | | | | | | | | | | | | |
| Direct Labor Utilization | | | | | | | | | | | | | | | |
| Cost of Quality | | | | | | | | | | | | | | | |
| Peacetime Utilization Index | | | | | | | | | | | | | | | |
| Productivity Index | | | | | | | | | | | | | | | |
| Cost Performance Index | | | | | | | | | | | | | | | |
| Innovation | | | | | | | | | | | | | | | |
| ▲ TOC Measures: | | | | | | | | | | | | | | | |
| Throughput (T) | | | | | | | | | | | | | | | |
| Inventory (I) | | | | | | | | | | | | | | | |
| Operating Expense (OE) | | | | | | | | | | | | | | | |
| T Dollar Days | | | | | | | | | | | | | | | |
| I Dollar Days | | | | | | | | | | | | | | | |
| I Turnover | | | | | | | | | | | | | | | |
| Net Profit | | | | | | | | | | | | | | | |

Figure 3.3: Cost vs. Measurement System Matrix

factor of competitiveness). To promote confidence in the results, two nonparametric tests -- the Kruskal-Wallis and the sign test -- were used.

Both tests were conducted for all three competitive edges, and within each edge, a variety of comparisons were performed. Since the study's focus was on whether or not there was a difference between DDPMS and TOC measures, the statistical tests concentrated on this question. The responses were tallied within each competitive edge (added up across the directorates for each specific measure, and then computed by adding up all "Y" answers for each management level within each measurement system). The results were aggregated across management levels and then separated by management level.

The first test performed was the Kruskal-Wallis test, which determined whether there was any difference between the two measurement systems. An $\alpha$ of 0.05 was selected as the confidence interval.

The null hypothesis was:

$H_0$: There is no difference between measurement systems.

and the alternate hypothesis was:

$H_a$: There is a difference between the measurement systems.

The formula for calculating test statistic "K" was:

$$K = \frac{12}{N(N+1)} \sum_{j=1}^{p} \frac{R_j^2}{n_j} - 3(N+1)$$

where:

$p$ = the number of samples

$n_j$ = the number of cases in the $j$th sample

$N = \sum n_j$, the total number of observations

$R_j$ = the sum of ranks in the $j$th sample

(Siegel 1956:185) (McLave and Benson 1991:975)


The ranks were arrived at by adding the number of yes responses in the matrix cells.  For instance, when testing within each specific measure, if seven people reported that Schedule Conformance related to cost, then the measure received a score of "7."  On the other hand, when testing between measurement systems, if a manager responded affirmatively to (for example) four of the seven measures in a measurement system, then the organization received a score of "4."  Because ties occurred in the ranking process, an adjustment was necessary:  tied measurements were assigned "average value of the ranks to each of the tied observations" (McLave and Benson, 1991:975).

The table values for the test statistic were found in the Chi square distribution table (Table F) in Lawrence

Lapin's text, <u>Statistics for Modern Business Decisions</u> (Lapin, 1973:725).

The next statistical test performed was the sign test. This nonparametric test, which followed Lapin's example (Lapin, 1973:416-418), was used tc determine whether the DDPMS measures were superior to TOC or visa versa. The same comparisons (i.e., the ranks) were used as for the Kruskal Wallis test. While the first nonparametric test showed whether a difference existed between the two systems, the sign test indicated which one, if either, was better. (Logically, the sign test would only be performed if the Kruskal-Wallis test indicated a significant difference.)

The null hypothesis was:

$H_O$: The median of the score differences is 0 (i.e., neither system is superior).

and the alternate hypothesis was:

$H_a$: The TOC-based measurement system is superior to DDPMS.

The differences between the scores were calculated. A negative number would result in a negative sign ranking (indicating that DDPMS received more "Y" answers than TOC), while a positive difference would result in a plus sign (indicating that TOC received more "Y" answers than DDPMS). If any ties resulted, it was assumed that there were differ-

ences too subtle to assess. Since it would be virtually impossible to identify these differences, the ties were not considered in the analysis.

Binomial distributions, taken from Beyer's Basic Statistical Tables (Beyer, 1971:41), were considered in this portion of the test. As in Lapin's example, if the probability of achieving "n" negative signs exceeds the $\alpha$ of 0.05, we would fail to reject the null hypothesis.

To calculate these statistics more quickly and reliably, spreadsheets using Borland International's Quattrc Pro application software were used for both the Kruskal-Wallis and the sign tests (Quattro Pro, 1991).

In order to assess the different kinds of data that managers collect and use under either measurement system to reflect improvement in the competitive edges, content analysis was used. This method is a means "of studying and analyzing communications in a systematic, objective, and quantitative manner . . . to determine the relative frequency of various communication phenomena" (Kerlinger, 1973:525). Essentially, the different possible data sources were identified, and then each time the managers mentioned a data source it was registered. In terms of content analysis, the data sources were categories (a word or group of words, in this case). The responses to associated measurement questions 7 and 9 comprised the universe (U). The quantification of the data was simply the counting of occasions that

respondents referred to a data source (Kerlinger, 1973:525-534).

Content analysis was also the method used to analyze the managers' answers to investigative question #5. In this case, U was the set of all responses to the question. The categories chosen were themes rather than words. For instance, comments were tabulated as "Negative comments about TOC" or "Belief that both systems have merit." As before, counting the occurrences of the themes was the method of quantifying the responses to the investigative question (Kerlinger, 1973:530).

## Summary

In this chapter, the research methods used to answer the investigative questions were discussed. The methods included a thorough literature review and statistical analysis of interview results. Chapter IV will discuss in detail the results of applying this methodology.

# IV. Results of the Research

## Introduction

This chapter discusses the results of the research using the methodology outlined in the previous chapter. First, the results of the nonparametric tests used to answer associated measurement questions 6 and 8 are shown and discussed. Next, content analysis of associated measurement questions 7 and 9 (using responses to interview question 3) is given. Finally, the answers to interview question 5 are examined using content analysis.

## The Nonparametric Tests

**Understanding the Measures.** The first test sought to discover the degree of understanding of the measures by the managers. This test highlights an important distinction: while some measures are not used because managers do not understand them, other measures are well understood, but not used.

In Figure 4.1, all management levels are included in the test. The scores are the result of tabulating "Y" (for "yes") responses and adding those responses for each manager. That is to say, Schedule Conformance received a score of "10," because all the managers understood it, whereas Cost Performance Index received a "2," because only two of the ten understood it. Figure 4.2 separates the upper management levels (directorate and division) and tests the

**DDPMS**

| Measure | Score | Rank |
|---|---|---|
| Schedule Conformance | 10 | 11 |
| Direct Labor Utilization | 10 | 11 |
| Cost of Quality | 10 | 11 |
| Peacetime Utilization Index | 3 | 4 |
| Productivity Index | 4 | 5 |
| Cost Performance Index | 2 | 3 |
| Innovation | 8 | 6.5 |

$$R_1 = 51.5$$

**TOC**

| Measure | Score | Rank |
|---|---|---|
| Throughput | 10 | 11 |
| Inventory | 10 | 11 |
| Operating Expense | 10 | 11 |
| Throughput Dollar Days | 1 | 1.5 |
| Inventory Dollar Days | 1 | 1.5 |
| Inventory Turnover | 10 | 11 |
| Net Profit | 8 | 6.5 |

$$R_2 = 53.5$$

| | |
|---|---|
| $N =$ | 14 |
| $n =$ | 7 |
| $K =$ | 0.016327 |
| $\chi 2 =$ | 3.841 |
| Result $=$ | Fail to Reject $H_0$ |

Maximum Score = 10.

$\chi^2$ is the chi square statistic with 1 degree of freedom
and an $\alpha$ of 0.05.

**Figure 4.1. Kruskal-Wallis Test Comparing
Understanding of the Measures:
DDPMS vs. TOC
(All Management Levels)**

**DDPMS**

| Measure | Score | Rank |
|---|---|---|
| Schedule Conformance | 4 | 10.5 |
| Direct Labor Utilization | 4 | 10.5 |
| Cost of Quality | 4 | 10.5 |
| Peacetime Utilization Index | 3 | 5 |
| Productivity Index | 3 | 5 |
| Cost Performance Index | 2 | 3 |
| Innovation | 4 | 10.5 |

$$R_1 = 55$$

**TOC**

| Measure | Score | Rank |
|---|---|---|
| Throughput | 4 | 10.5 |
| Inventory | 4 | 10.5 |
| Operating Expense | 4 | 10.5 |
| Throughput Dollar Days | 0 | 1 |
| Inventory Dollar Days | 1 | 2 |
| Inventory Turnover | 4 | 10.5 |
| Net Profit | 3 | 5 |

$$R_2 = 50$$

| | |
|---|---|
| $N =$ | 14 |
| $n =$ | 7 |
| $K =$ | 0.102041 |
| $\chi 2 =$ | 3.841 |
| Result = | Fail to Reject $H_o$ |

Maximum Score = 4.

$\chi^2$ is the chi square statistic with 1 degree of freedom and an $\alpha$ of 0.05.

**Figure 4.2. Kruskal-Wallis Test Comparing Understanding of the Measures: DDPMS vs. TOC (Upper Management Levels)**

understanding of the measures. Figure 4.3 does the same with lower echelons (branch level). The Kruskal-Wallis test was used to discover whether significant differences in the two categories (DDPMS and TOC) existed. It is apparent from the tests that the systems of measures were not statistically different with respect to how well they were understood by the two management levels.

Managers' definitions of the measurements were judged liberally. In other words, they did not have to recite a book definition. As long as they had a reasonable under-standing of the measure, they were considered to understand it. The tests showed no difference between the understand-ing of the two measurement systems at either management level. Poorly understood measures (measures that received scores of four or below) at both levels of management included Peacetime Utilization Index, Productivity Index, and Cost Performance Index for DDPMS; and Throughput Dollar Days and Inventory Dollar Days for TOC.

The original set of research questions did not address the possibility of differences in understanding between the echelons of management. The thrust of the research was to discover the understanding and usefulness of the measures and which system (if either) was better, hence the focus on the differences in the measurement system and not in manage-ment levels. However, during the study, it became clear that differences of understanding between the echelons could

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**DDPMS**

| Measure | Score | Rank |
|---|---|---|
| Schedule Conformance | 6 | 11 |
| Direct Labor Utilization | 6 | 11 |
| Cost of Quality | 6 | 11 |
| Peacetime Utilization Index | 0 | 2 |
| Productivity Index | 1 | 4.5 |
| Cost Performance Index | 0 | 2 |
| Innovation | 4 | 6 |

$$R_1 = \quad 47.5$$

**TOC**

| Measure | Score | Rank |
|---|---|---|
| Throughput | 6 | 11 |
| Inventory | 6 | 11 |
| Operating Expense | 6 | 11 |
| Throughput Dollar Days | 1 | 4.5 |
| Inventory Dollar Days | 0 | 2 |
| Inventory Turnover | 6 | 11 |
| Net Profit | 5 | 7 |

$$R_2 = \quad 57.5$$

| | |
|---|---|
| $N =$ | 14 |
| $n =$ | 7 |
| $K =$ | 0.408163 |
| $\chi 2 =$ | 3.841 |
| Result $=$ | Fail to Reject $H_0$ |

Maximum Score = 6.

$\chi^2$ is the chi square statistic with 1 degree of freedom
and an $\alpha$ of 0.05.

**Figure 4.3. Kruskal-Wallis Test Comparing
Understanding of the Measures:
DDPMS vs. TOC
(Lower Management Levels)**

indicate a cause for ineffective implementation. In addition, disagreement about the usefulness of the measurement systems might also have an adverse effect on implementation.

The character of the data to be compared (i.e., small sample size with categories of unequal number; namely, four in upper management and six in lower management) permitted the use of either the extension of the median test or the Kruskal-Wallis test. According to Siegel, either is applicable, but the Kruskal-Wallis is more efficient, because it uses more of the information of the observations, and it is "more sensitive to differences in $\underline{k}$ samples of scores" (Siegel, 1956:194).

Preliminary calculations using the Kruskal-Wallis test showed that the difference between the $R_1$'s or the $R_2$'s would have to exceed 30 to indicate any significant difference in the high and low management levels. (See Figure 4.4 for an example of a comparison between levels of management.) Coincidentally, the greatest difference between the $R_1$ and the $R_2$ values (a difference of 25) occurred in the tests for understanding of the TOC measures. Figure 4.4 shows that there was no significant difference between the levels of management insofar as they understood the measures. Since this level of difference was not exceeded in any of the other tests, it was concluded that no difference existed between management echelons either in understanding or use.

**TOC (upper levels)**

| Measure | Score | Rank |
|---|---|---|
| Throughput | 4 | 7.5 |
| Inventory | 4 | 7.5 |
| Operating Expense | 4 | 7.5 |
| Throughput Dollar Days | 0 | 1.5 |
| Inventory Dollar Days | 1 | 3.5 |
| Inventory Turnover | 4 | 7.5 |
| Net Profit | 3 | 5 |

$R_1 = 40$

**TOC (lower levels)**

| Measure | Score | Rank |
|---|---|---|
| Throughput | 6 | 12.5 |
| Inventory | 6 | 12.5 |
| Operating Expense | 6 | 12.5 |
| Throughput Dollar Days | 1 | 3.5 |
| Inventory Dollar Days | 0 | 1.5 |
| Inventory Turnover | 6 | 12.5 |
| Net Profit | 5 | 10 |

$R_2 = 65$

| | |
|---|---|
| $N =$ | 14 |
| $n =$ | 7 |
| $K =$ | 2.5510203 |
| $\chi 2 =$ | 3.841 |
| Result = | Fail to Reject $H_0$ |

Maximum Score = 4 for Upper, 6 for Lower.
$\chi^2$ is the chi square statistic with 1 degree of freedom
and an $\alpha$ of 0.05.

**Figure 4.4. Kruskal-Wallis Test Comparing
Upper vs. Lower Management Levels:
Understanding of TOC Measures**

Usefulness of the Measures. The next test was to discover the degree to which managers used the measures relative to the competitive edge of quality. Again, three tests -- all management levels, high echelons, and low echelons -- were performed (see Figures 4.5 through 4.7). No significant difference existed between the use of the measurement systems relative to quality at any functional level.

The raw scores showed managers used very few of these measures as indicators of quality. No single measure received a score higher than half the maximum possible score. For instance, in Figure 4.5, the highest-scoring DDPMS measure, Schedule Conformance and the highest-scoring TOC measure, Throughput, each received scores of five out of a possible ten. Managers who answered yes explained that these measures gave them indirect measures of quality. For instance, one manager said that Throughput would be greater with better quality because, "We sell more if the quality is higher." One manager stated (concerning Schedule Conformance) that a shoddy product would disrupt the schedule, explaining: "If you turn out a product that meets the schedule, it is a quality product."

Interestingly, Cost of Quality (COQ) scored poorly as a useful measure for telling managers how they are performing with respect to quality. Only one of the four upper-level managers thought the measure had value as a quality measure

**DDPMS**

| Measure | Score | Rank |
|---|---|---|
| Schedule Conformance | 5 | 13.5 |
| Direct Labor Utilization | 1 | 6.5 |
| Cost of Quality | 3 | 11 |
| Peacetime Utilization Index | 0 | 2.5 |
| Productivity Index | 1 | 6.5 |
| Cost Performance Index | 0 | 2.5 |
| Innovation | 2 | 9 |

$$R_1 = 51.5$$

**TOC**

| Measure | Score | Rank |
|---|---|---|
| Throughput | 5 | 13.5 |
| Inventory | 1 | 6.5 |
| Operating Expense | 3 | 11 |
| Throughput Dollar Days | 0 | 2.5 |
| Inventory Dollar Days | 0 | 2.5 |
| Inventory Turnover | 1 | 6.5 |
| Net Profit | 3 | 11 |

$$R_2 = 53.5$$

| | |
|---|---|
| N = | 14 |
| n = | 7 |
| K = | 0.016327 |
| $\chi 2$ = | 3.841 |
| Result = | Fail to Reject $H_o$ |

Maximum Score = 10.
$\chi^2$ is the chi square statistic with 1 degree of freedom
and an $\alpha$ of 0.05.

**Figure 4.5. Kruskal-Wallis Test Comparing
Use of Measures to Compete on Basis of Quality:
DDPMS vs. TOC
(All Management Levels)**

**DDPMS**

| Measure | Score | Rank |
|---|---|---|
| Schedule Conformance | 2 | 13 |
| Direct Labor Utilization | 0 | 4.5 |
| Cost of Quality | 1 | 10 |
| Peacetime Utilization Index | 0 | 4.5 |
| Productivity Index | 0 | 4.5 |
| Cost Performance Index | 0 | 4.5 |
| Innovation | 2 | 13 |

$$R_1 = 54$$

**TOC**

| Measure | Score | Rank |
|---|---|---|
| Throughput | 2 | 13 |
| Inventory | 0 | 4.5 |
| Operating Expense | 1 | 10 |
| Throughput Dollar Days | 0 | 4.5 |
| Inventory Dollar Days | 0 | 4.5 |
| Inventory Turnover | 0 | 4.5 |
| Net Profit | 1 | 10 |

$$R_2 = 51$$

| | |
|---|---|
| $N =$ | 14 |
| $n =$ | 7 |
| $K =$ | 0.036735 |
| $\chi^2 =$ | 3.841 |
| Result $=$ | Fail to Reject $H_0$ |

Maximum Score = 4.
$\chi^2$ is the chi square statistic with 1 degree of freedom
and an $\alpha$ of 0.05.

**Figure 4.6. Kruskal-Wallis Test Comparing
Use of Measures to Compete on Basis of Quality:
DDPMS vs. TOC
(Upper Management Levels)**

**DDPMS**

| Measure | Score | Rank |
|---|---|---|
| Schedule Conformance | 3 | 13.5 |
| Direct Labor Utilization | 1 | 7.5 |
| Cost of Quality | 2 | 11 |
| Peacetime Utilization Index | 0 | 3 |
| Productivity Index | 1 | 7.5 |
| Cost Performance Index | 0 | 3 |
| Innovation | 0 | 3 |

$$R_1 = 48.5$$

**TOC**

| Measure | Score | Rank |
|---|---|---|
| Throughput | 3 | 13.5 |
| Inventory | 1 | 7.5 |
| Operating Expense | 2 | 11 |
| Throughput Dollar Days | 0 | 3 |
| Inventory Dollar Days | 0 | 3 |
| Inventory Turnover | 1 | 7.5 |
| Net Profit | 2 | 11 |

$$R_2 = 56.5$$

| | |
|---|---|
| N = | 14 |
| n = | 7 |
| K = | 0.261224 |
| $\chi^2$ = | 3.841 |
| Result = | Fail to Reject $H_0$ |

Maximum Score = 6.
$\chi^2$ is the chi square statistic with 1 degree of freedom
and an $\alpha$ of 0.05.

**Figure 4.7. Kruskal-Wallis Test Comparing
Use of Measures to Compete on Basis of Quality:
DDPMS vs. TOC
(Lower Management Levels)**

(Figure 4.6), while only two of the six lower-echelon managers considered it useful (Figure 4.7). Managers believed that COQ was an inadequate quality measure for one main reason: the measure requires an extensive, real-time data-collection capability that simply did not yet exist. Scrap and rework figures were still largely invisible. While all managers understood the measure, and most believed COQ data would be useful to compete on the basis of quality, the information was not available.

The next set of tests (Figures 4.8 through 4.10) compared the usefulness of the measures with respect to delivery. Again, the Kruskal-Wallis tests showed no difference between the two systems of measures relative to delivery at high management levels, low management levels, or all levels combined.

Schedule Conformance (for DDPMS) scored with a perfect ten of ten (Figure 4.8), meaning that all managers in the study considered it a useful measure for delivery. Throughput (for TOC) received the fairly high score of seven out of ten. Reasons for not using Throughput included lack of data for the measure. As one upper-level manager put it, "The tools are not in place yet."

As a percentage, more lower-level managers than upper-level managers considered Direct Labor Utilization (DLU) a good measure with respect to delivery (DLU scored the same as Throughput, i.e., four out of six). Such high scores for

**DDPMS**

| Measure | Score | Rank |
|---|---|---|
| Schedule Conformance | 10 | 14 |
| Direct Labor Utilization | 5 | 11.5 |
| Cost of Quality | 4 | 9.5 |
| Peacetime Utilization Index | 0 | 2.5 |
| Productivity Index | 2 | 6 |
| Cost Performance Index | 0 | 2.5 |
| Innovation | 2 | 6 |

$$R_1 = 52$$

**TOC**

| Measure | Score | Rank |
|---|---|---|
| Throughput | 7 | 13 |
| Inventory | 5 | 11.5 |
| Operating Expense | 2 | 6 |
| Throughput Dollar Days | 0 | 2.5 |
| Inventory Dollar Days | 0 | 2.5 |
| Inventory Turnover | 4 | 9.5 |
| Net Profit | 3 | 8 |

$$R_2 = 53$$

| | |
|---|---|
| $N =$ | 14 |
| $n =$ | 7 |
| $K =$ | 0.004082 |
| $\chi^2 =$ | 3.841 |
| Result = | Fail to Reject $H_0$ |

Maximum Score = 10.
$\chi^2$ is the chi square statistic with 1 degree of freedom
and an $\alpha$ of 0.05.

**Figure 4.8. Kruskal-Wallis Test Comparing
Use of Measures to Compete on Basis of Delivery:
DDPMS vs. TOC
(All Management Levels)**

## DDPMS

| Measure | Score | Rank |
|---|---|---|
| Schedule Conformance | 4 | 14 |
| Direct Labor Utilization | 1 | 7.5 |
| Cost of Quality | 1 | 7.5 |
| Peacetime Utilization Index | 0 | 3 |
| Productivity Index | 1 | 7.5 |
| Cost Performance Index | 0 | 3 |
| Innovation | 2 | 11 |

$$R_1 = 53.5$$

## TOC

| Measure | Score | Rank |
|---|---|---|
| Throughput | 3 | 13 |
| Inventory | 2 | 11 |
| Operating Expense | 0 | 3 |
| Throughput Dollar Days | 0 | 3 |
| Inventory Dollar Days | 0 | 3 |
| Inventory Turnover | 2 | 11 |
| Net Profit | 1 | 7.5 |

$$R_2 = 51.5$$

| | |
|---|---|
| $N =$ | 14 |
| $n =$ | 7 |
| $K =$ | 0.016327 |
| $\chi 2 =$ | 3.841 |
| Result = | Fail to Reject $H_o$ |

Maximum Score = 4.
$\chi^2$ is the chi square statistic with 1 degree of freedom
and an $\alpha$ of 0.05.

**Figure 4.9. Kruskal-Wallis Test Comparing
Use of Measures to Compete on Basis of Delivery:
DDPMS vs. TOC
(Upper Management Levels)**

4-14

**DDPMS**

| Measure | Score | Rank |
|---|---|---|
| Schedule Conformance | 6 | 14 |
| Direct Labor Utilization | 4 | 12.5 |
| Cost of Quality | 3 | 10.5 |
| Peacetime Utilization Index | 0 | 3 |
| Productivity Index | 1 | 6 |
| Cost Performance Index | 0 | 3 |
| Innovation | 0 | 3 |

$$R_1 = 52$$

**TOC**

| Measure | Score | Rank |
|---|---|---|
| Throughput | 4 | 12.5 |
| Inventory | 3 | 10.5 |
| Operating Expense | 2 | 8 |
| Throughput Dollar Days | 0 | 3 |
| Inventory Dollar Days | 0 | 3 |
| Inventory Turnover | 2 | 8 |
| Net Profit | 2 | 8 |

$$R_2 = 53$$

| | |
|---|---|
| $N$ = | 14 |
| $n$ = | 7 |
| $K$ = | 0.004082 |
| $\chi 2$ = | 3.841 |
| Result = | Fail to Reject $H_0$ |

Maximum Score = 6.

$\chi^2$ is the chi square statistic with 1 degree of freedom and an $\alpha$ of 0.05.

**Figure 4.10. Kruskal-Wallis Test Comparing
Use of Measures to Compete on Basis of Delivery:
DDPMS vs. TOC
(Lower Management Levels)**

DLU as a delivery measure might indicate poor understanding of the measure's intended usage. On the other hand, it might indicate that these managers recognize the need for delivery measures and are willing to use a measure that is only tangentially related to delivery. A lower-echelon manager who answered yes for Direct Labor Utilization as a delivery indicator said, "Fifty-percent efficiency means you probably are falling behind in delivery, assuming the schedule is good [i.e., accurate]."

Other measures scored poorly because they were either considered only remotely connected to delivery or because they simply did not relate at all. For instance, regarding Net Profit (under TOC) one manager acknowledged a "loose connection" between the measure and delivery performance, but thought it was dangerous to rely on it because doing so could invite suboptimization of the system.

It is worth noting here that Throughput Dollar Days (TDD) would be a useful measure for delivery, but only one manager understood the measure, and he was unaware of its applicability, believing it was "not useful in the depot setting." TDD is simply the value of the order multiplied by the number of days late. In this way, a manager can not only track how late an order is, but also appreciate how its lateness hurts the organization, because the order's value is factored in.

Following the statistical tests for delivery, tests comparing the usefulness of the measures with respect to cost as a competitive edge were accomplished (see Figures 4.11 through 4.13). Once again, at all management levels, the tests detected no significant difference in the usefulness of the measures relative to cost. Not surprisingly, Operating Expense under TOC received a high score. All ten managers agreed that it gave a good indication as to how well they were performing with respect to cost.

Besides this obvious measure, Throughput and Direct Labor Utilization received high scores. A slight discrepancy was noted between the high and low management echelons concerning Direct Labor Utilization. Half of the upper-level managers considered the measure useful with respect to cost, while five of the six lower-level managers deemed it useful. For the branch managers, Direct Labor Utilization was closely related to earned hours, wasted hours, and the costs of overtime. This caused them to consider it a useful measure.

Another expected high scorer was the TOC measure of Net Profit as a cost indicator. Most managers were well aware of their figures for this measure, and some even had posted them on their walls. For them, the goal was to remain near zero. Some expressed concern that their area made a profit in order to balance out other ALC areas that were losing money. Even if they could reduce their costs of doing busi-

## DDPMS

| Measure | Score | Rank |
|---|---|---|
| Schedule Conformance | 4 | 9 |
| Direct Labor Utilization | 7 | 12 |
| Cost of Quality | 4 | 9 |
| Peacetime Utilization Index | 0 | 2 |
| Productivity Index | 2 | 6 |
| Cost Performance Index | 1 | 4.5 |
| Innovation | 1 | 4.5 |

$$R_1 = 47$$

## TOC

| Measure | Score | Rank |
|---|---|---|
| Throughput | 7 | 12 |
| Inventory | 4 | 9 |
| Operating Expense | 10 | 14 |
| Throughput Dollar Days | 0 | 2 |
| Inventory Dollar Days | 0 | 2 |
| Inventory Turnover | 3 | 7 |
| Net Profit | 7 | 12 |

$$R_2 = 58$$

| | |
|---|---|
| $N =$ | 14 |
| $n =$ | 7 |
| $K =$ | 0.493991 |
| $\chi 2 =$ | 3.841 |
| Result = | Fail to Reject $H_o$ |

Maximum Score = 10.

$\chi^2$ is the chi square statistic with 1 degree of freedom
and an $\alpha$ of 0.05.

**Figure 4.11. Kruskal-Wallis Test Comparing
Use of Measures Compete on Basis of Cost:
DDPMS vs. TOC
(All Management Levels)**

**DDPMS**

| Measure | Score | Rank |
|---|---|---|
| Schedule Conformance | 2 | 9 |
| Direct Labor Utilization | 2 | 9 |
| Cost of Quality | 2 | 9 |
| Peacetime Utilization Index | 0 | 2 |
| Productivity Index | 1 | 5 |
| Cost Performance Index | 1 | 5 |
| Innovation | 1 | 5 |

$R_1 =$ 44

**TOC**

| Measure | Score | Rank |
|---|---|---|
| Throughput | 3 | 12.5 |
| Inventory | 2 | 9 |
| Operating Expense | 4 | 14 |
| Throughput Dollar Days | 0 | 2 |
| Inventory Dollar Days | 0 | 2 |
| Inventory Turnover | 2 | 9 |
| Net Profit | 3 | 12.5 |

$R_2 =$ 61

| | |
|---|---|
| N = | 14 |
| n = | 7 |
| K = | 1.179592 |
| $\chi^2$ = | 3.841 |
| Result = | Fail to Reject $H_0$ |

Maximum Score = 4.

$\chi^2$ is the chi square statistic with 1 degree of freedom
and an $\alpha$ of 0.05.

**Figure 4.12. Kruskal-Wallis Test Comparing
Use of Measures to Compete on Basis of Cost:
DDPMS vs. TOC
(Upper Management Levels)**

**DDPMS**

| Measure | Score | Rank |
|---|---|---|
| Schedule Conformance | 2 | 9 |
| Direct Labor Utilization | 5 | 13 |
| Cost of Quality | 2 | 9 |
| Peacetime Utilization Index | 0 | 3 |
| Productivity Index | 1 | 6.5 |
| Cost Performance Index | 0 | 3 |
| Innovation | 0 | 3 |

$$R_1 = 46.5$$

**TOC**

| Measure | Score | Rank |
|---|---|---|
| Throughput | 4 | 11.5 |
| Inventory | 2 | 9 |
| Operating Expense | 6 | 14 |
| Throughput Dollar Days | 0 | 3 |
| Inventory Dollar Days | 0 | 3 |
| Inventory Turnover | 1 | 6.5 |
| Net Profit | 4 | 11.5 |

$$R_2 = 58.5$$

| | |
|---|---|
| $N$ = | 14 |
| $n$ = | 7 |
| $K$ = | 0.587755 |
| $\chi 2$ = | 3.841 |
| Result = | Fail to Reject $H_0$ |

Maximum Score = 6.
$\chi^2$ is the chi square statistic with 1 degree of freedom
and an $\alpha$ of 0.05.

**Figure 4.13. Kruskal-Wallis Test Comparing
Use of Measures to Compete on Basis of Cost:
DDPMS vs. TOC
(Lower Management Levels)**

4-20

ness, they could not reduce the prices they charged, because the resultant excess revenues went to compensate negative revenue conditions elsewhere so that the ALC as a whole showed zero net profit. Those managers who turned a profit had mixed feelings; they were happy and proud to help the ALC balance its net profit, but they were dismayed that after they improved processes and cut costs, they could not lower their products' prices to the customer.

Although none of the tests comparing the two sets of measures to the various competitive edges indicated any statistical difference, it could have been possible that there was a discernible difference if the scores had been combined. Comparing each edge separately might obscure the results -- since the measures were not designed to necessarily match one for one with quality, delivery, and cost -- but comparing the sets of measures to the aggregated responses for all three edges might expose a statistical difference between the two measurement systems. The question is whether the result would be different if the measure received a "Y" score as long as it was considered useful in at least one category. Figures 4.14 through 4.16 represent such a "composite" treatment. Essentially, the tabulated score means that the measure is being used in some way relative to at least one factor of competitiveness.

However, as before, the results showed no statistical difference between the measurement systems regardless of the

**DDPMS**

| Measure | Score | Rank |
|---|---|---|
| Schedule Conformance | 10 | 13.5 |
| Direct Labor Utilization | 8 | 10.5 |
| Cost of Quality | 6 | 8.5 |
| Peacetime Utilization Index | 0 | 2 |
| Productivity Index | 3 | 6 |
| Cost Performance Index | 1 | 4 |
| Innovation | 2 | 5 |

$$R_1 = 49.5$$

**TOC**

| Measure | Score | Rank |
|---|---|---|
| Throughput | 9 | 12 |
| Inventory | 6 | 8.5 |
| Operating Expense | 10 | 13.5 |
| Throughput Dollar Days | 0 | 2 |
| Inventory Dollar Days | 0 | 2 |
| Inventory Turnover | 5 | 7 |
| Net Profit | 8 | 10.5 |

$$R_2 = 55.5$$

| | |
|---|---|
| N = | 14 |
| n = | 7 |
| K = | 0.146939 |
| $\chi2$ = | 3.841 |
| Result = | Fail to Reject $H_0$ |

Maximum Score = 10.

$\chi^2$ is the chi square statistic with 1 degree of freedom
and an $\alpha$ of 0.05.

**Figure 4.14. Kruskal-Wallis Test Comparing
Use of Measures to Compete on Basis of Any Edge:
DDPMS vs. TOC
(All Management Levels)**

**DDPMS**

| Measure | Score | Rank |
|---|---|---|
| Schedule Conformance | 4 | 13.5 |
| Direct Labor Utilization | 2 | 7 |
| Cost of Quality | 2 | 7 |
| Peacetime Utilization Index | 0 | 2 |
| Productivity Index | 2 | 7 |
| Cost Performance Index | 1 | 4 |
| Innovation | 2 | 7 |

$$R_1 = \ 47.5$$

**TOC**

| Measure | Score | Rank |
|---|---|---|
| Throughput | 3 | 11 |
| Inventory | 2 | 7 |
| Operating Expense | 4 | 13.5 |
| Throughput Dollar Days | 0 | 2 |
| Inventory Dollar Days | 0 | 2 |
| Inventory Turnover | 3 | 11 |
| Net Profit | 3 | 11 |

$$R_2 = \ 57.5$$

| | |
|---|---|
| N = | 14 |
| n = | 7 |
| K = | 0.408163 |
| $\chi 2$ = | 3.841 |
| Result = | Fail to Reject $H_0$ |

Maximum Score = 4.

$\chi^2$ is the chi square statistic with 1 degree of freedom and an $\alpha$ of 0.05.

**Figure 4.15. Kruskal-Wallis Test Comparing Use of Measures to Compete on Basis of Any Edge: DDPMS vs. TOC (Upper Management Levels)**

**DDPMS**

| Measure | Score | Rank |
|---|---|---|
| Schedule Conformance | 6 | 12.5 |
| Direct Labor Utilization | 6 | 12.5 |
| Cost of Quality | 4 | 8.5 |
| Peacetime Utilization Index | 0 | 3 |
| Productivity Index | 1 | 6 |
| Cost Performance Index | 0 | 3 |
| Innovation | 0 | 3 |

$$R_1 = 48.5$$

**TOC**

| Measure | Score | Rank |
|---|---|---|
| Throughput | 6 | 12.5 |
| Inventory | 4 | 8.5 |
| Operating Expense | 6 | 12.5 |
| Throughput Dollar Days | 0 | 3 |
| Inventory Dollar Days | 0 | 3 |
| Inventory Turnover | 2 | 7 |
| Net Profit | 5 | 10 |

$$R_2 = 56.5$$

| | |
|---|---|
| $N$ = | 14 |
| $n$ = | 7 |
| $K$ = | 0.261224 |
| $\chi^2$ = | 3.841 |
| Result = | Fail to Reject $H_0$ |

Maximum Score = 6.

$\chi^2$ is the chi square statistic with 1 degree of freedom and an $\alpha$ of 0.05.

**Figure 4.16. Kruskal-Wallis Test Comparing
Use of Measures to Compete on Basis of Any Edge:
DDPMS vs. TOC
(Lower Management Levels)**

management level. If a score of seven to ten (Figure 4.14) is considered a good score when judging the usefulness of a measure, then DDPMS has two measures and TOC has three measures that are useful for giving managers the information they need to compete on quality, delivery, or cost. The rest of the measures do not relate strongly (a score of seven to ten) to the competitive edges.

Both measurement systems were obviously hampered by low scores for measures that were not understood. For instance, only one person could define Inventory Dollar Days, and he said, "We don't look at it." Many of the managers had obviously received training in TOC, but had never heard of the terms Throughput Dollar Days or Inventory Dollar Days.

Most managers (eight of ten) could define innovation, but in the aggregate, only two of them, the division-level managers, believed it related to any of the competitive edges. Many thought it was too subjective to be of any use. As one directorate manager explained, "I don't know how you measure it."

None of the tests presented so far revealed any difference between TOC-based measures and DDPMS. Therefore, an analysis based on the organizational tabulation of scores was conducted. Figures 4.17 through 4.19 and Figure 4.21 show the results of tests constructed in this way. (Figure 4-20 is the sign test for Figure 4.19.) The scores represent a management level's assessment of the usefulness

**DDPMS**

| Management Level | Score | Rank |
|---|---|---|
| Directorate 1 | 0 | 4.5 |
| Division 1A | 3 | 17.5 |
| Branch 1A1 | 0 | 4.5 |
| Branch 1A2 | 1 | 11.5 |
| Branch 1A3 | 0 | 4.5 |
| Directorate 2 | 1 | 11.5 |
| Division 2A | 1 | 11.5 |
| Branch 2A1 | 0 | 4.5 |
| Branch 2A2 | 4 | 19 |
| Branch 2A3 | 2 | 15.5 |

$$R_1 = 104.5$$

**TOC**

| Management Level | Score | Rank |
|---|---|---|
| Directorate 1 | 1 | 11.5 |
| Division 1A | 2 | 15.5 |
| Branch 1A1 | 0 | 4.5 |
| Branch 1A2 | 0 | 4.5 |
| Branch 1A3 | 0 | 4.5 |
| Directorate 2 | 1 | 11.5 |
| Division 2A | 0 | 4.5 |
| Branch 2A1 | 1 | 11.5 |
| Branch 2A2 | 5 | 20 |
| Branch 2A3 | 3 | 17.5 |

$$R_2 = 105.5$$

| | |
|---|---|
| N = | 20 |
| n = | 10 |
| K = | 0.001429 |
| $\chi^2$ | 3.841 |
| Result = | Fail to Reject $H_o$ |

Maximum score = 7

$\chi^2$ is the chi square statistic with 1 degree of freedom, $\alpha$ of 0.05

**Figure 4.17. Kruskal-Wallis Test Comparing
All Managers' Evaluations of the Measures as Related to Quality:
DDPMS vs. TOC
(Organizational Tabulation)**

**DDPMS**

| Management Level | Score | Rank |
|---|---|---|
| Directorate 1 | 1 | 4.5 |
| Division 1A | 4 | 18 |
| Branch 1A1 | 1 | 4.5 |
| Branch 1A2 | 2 | 10.5 |
| Branch 1A3 | 3 | 15 |
| Directorate 2 | 2 | 10.5 |
| Division 2A | 2 | 10.5 |
| Branch 2A1 | 1 | 4.5 |
| Branch 2A2 | 4 | 18 |
| Branch 2A3 | 3 | 15 |

$$R_1 = 111$$

**TOC**

| Management Level | Score | Rank |
|---|---|---|
| Directorate 1 | 2 | 10.5 |
| Division 1A | 4 | 18 |
| Branch 1A1 | 0 | 1 |
| Branch 1A2 | 1 | 4.5 |
| Branch 1A3 | 2 | 10.5 |
| Directorate 2 | 1 | 4.5 |
| Division 2A | 1 | 4.5 |
| Branch 2A1 | 3 | 15 |
| Branch 2A2 | 5 | 20 |
| Branch 2A3 | 2 | 10.5 |

$$R_2 = 99$$

| | |
|---|---|
| $N =$ | 10 |
| $n =$ | 10 |
| $K =$ | 0.205714 |
| $\chi^2$ | 3.841 |
| Result = | Fail to Reject $H_0$ |

Maximum score = 7

$\chi^2$ is the chi square statistic with 1 degree of freedom, $\alpha$ of 0.05

**Figure 4.18. Kruskal-Wallis Test Comparing
All Managers' Evaluations of the Measures as Related to Delivery
DDPMS vs. TOC
(Organizational Tabulation)**

**DDPMS**

| Management Level | Score | Rank |
|---|---|---|
| Directorate 1 | 1 | 4.5 |
| Division 1A | 1 | 4.5 |
| Branch 1A1 | 1 | 4.5 |
| Branch 1A2 | 1 | 4.5 |
| Branch 1A3 | 0 | 1 |
| Directorate 2 | 2 | 9.5 |
| Division 2A | 2 | 9.5 |
| Branch 2A1 | 1 | 4.5 |
| Branch 2A2 | 4 | 18 |
| Branch 2A3 | 2 | 9.5 |

$$R_1 = 70$$

**TOC**

| Management Level | Score | Rank |
|---|---|---|
| Directorate 1 | 4 | 18 |
| Division 1A | 4 | 18 |
| Branch 1A1 | 3 | 13.5 |
| Branch 1A2 | 4 | 18 |
| Branch 1A3 | 3 | 13.5 |
| Directorate 2 | 3 | 13.5 |
| Division 2A | 3 | 13.5 |
| Branch 2A1 | 1 | 4.5 |
| Branch 2A2 | 4 | 18 |
| Branch 2A3 | 2 | 9.5 |

$$R_2 = 140$$

| | |
|---|---|
| N = | 20 |
| n = | 10 |
| K = | 7 |
| $\chi^2$ | 3.841 |
| Result = | Reject $H_o$ |

Maximum score = 7

$\chi^2$ is the chi square statistic with 1 degree of freedom, $\alpha$ of 0.05

**Figure 4.19. Kruskal-Wallis Test Comparing
All Managers' Evaluations of the Measures as Related to Cost:
DDPMS vs. TOC
(Organizational Tabulation)**

Net Score Received

| TOC | DDPMS | Difference | Sign | Value |
|---|---|---|---|---|
| 4 | 1 | 3 | + | 0 |
| 4 | 1 | 3 | + | 0 |
| 3 | 1 | 2 | + | 0 |
| 4 | 1 | 3 | + | 0 |
| 3 | 0 | 3 | + | 0 |
| 3 | 2 | 1 | + | 0 |
| 3 | 2 | 1 | + | 0 |
| 1 | 1 | 0 | tie | |
| 4 | 4 | 0 | tie | |
| 2 | 2 | 0 | tie | |

Number of Negative Signs or $P[R \leq ?]$ =     0

Sample Size for Binomial Distribution Computation =     7

$P[R \leq 0]$     0.0078   Significant Differences, $\therefore$ Reject Null Hypothesis.

TOC is better than DDPMS when judged on the basis of cost.

**Figure 4.20. Sign Test of All Managers' Evaluations
as Related to Cost: DDPMS vs. TOC**

**DDPMS**

| Management Level | Score | Rank |
|---|---|---|
| Directorate 1 | 1 | 1 |
| Division 1A | 4 | 14.5 |
| Branch 1A1 | 2 | 3 |
| Branch 1A2 | 2 | 3 |
| Branch 1A3 | 3 | 8 |
| Directorate 2 | 2 | 3 |
| Division 2A | 6 | 20 |
| Branch 2A1 | 3 | 8 |
| Branch 2A2 | 4 | 14.5 |
| Branch 2A3 | 3 | 8 |

$$R_1 = 83$$

**TOC**

| Management Level | Score | Rank |
|---|---|---|
| Directorate 1 | 4 | 14.5 |
| Division 1A | 5 | 18.5 |
| Branch 1A1 | 3 | 8 |
| Branch 1A2 | 4 | 14.5 |
| Branch 1A3 | 4 | 14.5 |
| Directorate 2 | 3 | 8 |
| Division 2A | 3 | 8 |
| Branch 2A1 | 4 | 14.5 |
| Branch 2A2 | 5 | 18.5 |
| Branch 2A3 | 3 | 8 |

$$R_2 = 127$$

| | |
|---|---|
| $N =$ | 20 |
| $n =$ | 10 |
| $K =$ | 2.765714 |
| $\chi^2$ | 3.814 |
| Result $=$ | Fail to Reject $H_o$ |

Maximum score = 7

$\chi^2$ is the chi square statistic with 1 degree of freedom, $\alpha$ of 0.05

**Figure 4.21. Kruskal-Wallis Test Comparing
All Managers' Evaluations of the Measures as Related to
the Three Edges Combined:
DDPMS vs. TOC
(Organizational Tabulation)**

of the measures within each system. For instance, Figure 4.17 shows that the Directorate 1 manager believed that none of the measures were useful with respect to quality -- hence the "0" in the score box. Under TOC, (Figure 4.17), the manager of Branch 2A2 thought five of the TOC measures were useful with respect to quality. As before in the previous Kruskal-Wallis tests, the scores were assigned ranks and compared using the $\underline{K}$ statistic to determine whether there was a significant difference.

The organizational tests for quality, delivery, and the combination of the three edges showed no statistical difference in TOC and DDPMS. The test for cost, however, did show a difference, which led to the sign test, the results of which are shown in Figure 4.19. This statistical test indicated that, with respect to cost, TOC was used by managers more than DDPMS, when the managers' evaluations of the measures were tabulated. This was the only case that showed a difference between the two systems.

Figure 4.17 reveals that managers are not using the measures for quality. Nine of the ten managers gave DDPMS an overall score of three or less. The same was true for TOC. This test strongly indicates that neither system is being used to drive performance with respect to the competitive edge of quality.

As Figures 4.19 and 4.20 show, TOC measures are significantly more useful for cost than DDPMS measures. The

point is that while both TOC and DDPMS have measures that are used with respect to cost (see Figure 4.11), as a system, TOC is significantly more useful for cost.

When all managers' evaluations were compared to the aggregated competitive edges (Figure 4.21) the results showed that three of the ten managers were using half or more of the DDPMS measures. Conversely, six of ten managers used half or more of the TOC measures. Although the difference between $R_1$ and $R_2$ may appear quite large, the test indicates that the differences cannot be considered significant.

The tests show that TOC and DDPMS are considered fairly equal in their usefulness (or lack thereof) with respect to the factors of competitiveness. They also indicate that neither system provides information managers need to compete on the basis of the quality, delivery, and cost -- either singly or in combination. To determine the degree to which both systems weakly correlate to the competitive edges, several tests were constructed that compared DDPMS with itself and TOC with itself, using actual versus "ideal" scores. Scores of "10" were entered for each DDPMS measure, and then for each TOC measure, and then compared to the actual scores derived from the interviews. These perfect scores represent hypothetical scores if all managers had understood and used the measure in relation to a least one of the factors of competitiveness.

The results of these tests are given in Figures 4.22 through 4.27. First, all management levels are shown, then upper management, and finally lower management. Seeing the actual scores compared with ideal scores within each measurement system highlights the shortcomings of TOC and DDPMS with respect to the aggregated competitive edges.

The $\underline{K}$ statistics range from one and one-half to nearly two times the value of the $\chi^2$ threshold for a 95 percent confidence interval. For instance, in Figure 4.25, the $\underline{K}$ statistic was 7.2, which was significantly outside the fail-to-reject range represented by the $\chi^2$ of 3.841. These results indicate the magnitude of how poorly the measurement systems relate to the factors of competitiveness identified in the literature.

Content Analysis: Data Used by Managers. When they were asked what kinds of data they collect for each of the measures with respect to a competitive edge, the depot managers gave a wide variety of answers. In order to understand their responses, content analysis was used. This method offered a convenient and logical way to account for all the data sources that were mentioned and to determine how frequently each one was named. The categories, then, are the words or groups of words that refer to a source of data. Counting the number of times managers mentioned a word or group of words is the method of quantification.

**DDPMS**

| Measure | Score | Rank |
|---|---|---|
| Schedule Conformance | 10 | 10.5 |
| Direct Labor Utilization | 8 | 6 |
| Cost of Quality | 6 | 5 |
| Peacetime Utilization Index | 0 | 1 |
| Productivity Index | 3 | 4 |
| Cost Performance Index | 1 | 2 |
| Innovation | 2 | 3 |

$$R_1 = 31.5$$

**DDPMS (if scores were perfect)**

| Measure | Score | Rank |
|---|---|---|
| Schedule Conformance | 10 | 10.5 |
| Direct Labor Utilization | 10 | 10.5 |
| Cost of Quality | 10 | 10.5 |
| Peacetime Utilization Index | 10 | 10.5 |
| Productivity Index | 10 | 10.5 |
| Cost Performance Index | 10 | 10.5 |
| Innovation | 10 | 10.5 |

$$R_2 = 73.5$$

| | |
|---|---|
| $N =$ | 14 |
| $n =$ | 7 |
| $K =$ | 7.2 |
| $\chi 2 =$ | 3.841 |
| Result $=$ | Reject $H_0$ |

Maximum Score = 10.
$\chi^2$ is the chi square statistic with 1 degree of freedom
and an $\alpha$ of 0.05.

**Figure 4.22  Kruskal-Wallis Test Comparing
Use of Measures to Compete on Basis of Any Edge:
DDPMS vs. DDPMS (Ideal)
(All Management Levels)**

**DDPMS**

| Measure | Score | Rank |
|---|---|---|
| Schedule Conformance | 4 | 10.5 |
| Direct Labor Utilization | 2 | 4.5 |
| Cost of Quality | 2 | 4.5 |
| Peacetime Utilization Index | 0 | 1 |
| Productivity Index | 2 | 4.5 |
| Cost Performance Index | 1 | 2 |
| Innovation | 2 | 4.5 |

$$R_1 = 31.5$$

**DDPMS (if scores were perfect)**

| Measure | Score | Rank |
|---|---|---|
| Schedule Conformance | 4 | 10.5 |
| Direct Labor Utilization | 4 | 10.5 |
| Cost of Quality | 4 | 10.5 |
| Peacetime Utilization Index | 4 | 10.5 |
| Productivity Index | 4 | 10.5 |
| Cost Performance Index | 4 | 10.5 |
| Innovation | 4 | 10.5 |

$$R_2 = 73.5$$

| | |
|---|---|
| $N =$ | 14 |
| $n =$ | 7 |
| $K =$ | 7.2 |
| $\chi^2 =$ | 3.841 |
| Result $=$ | Reject $H_o$ |

Maximum Score = 4.
$\chi^2$ is the chi square statistic with 1 degree of freedom
and an $\alpha$ of 0.05.

**Figure 4.23. Kruskal-Wallis Test Comparing
Use of Measures to Compete on Basis of Any Edge:
DDPMS vs. DDPMS (Ideal)
(Upper Management Levels)**

**DDPMS**

| Measure | Score | Rank |
|---|---|---|
| Schedule Conformance | 6 | 10 |
| Direct Labor Utilization | 6 | 10 |
| Cost of Quality | 4 | 5 |
| Peacetime Utilization Index | 0 | 2 |
| Productivity Index | 1 | 4 |
| Cost Performance Index | 0 | 2 |
| Innovation | 0 | 2 |

$$R_1 = 35$$

**DDPMS (if scores were perfect)**

| Measure | Score | Rank |
|---|---|---|
| Schedule Conformance | 6 | 10 |
| Direct Labor Utilization | 6 | 10 |
| Cost of Quality | 6 | 10 |
| Peacetime Utilization Index | 6 | 10 |
| Productivity Index | 6 | 10 |
| Cost Performance Index | 6 | 10 |
| Innovation | 6 | 10 |

$$R_2 = 70$$

| | |
|---|---|
| $N =$ | 14 |
| $n =$ | 7 |
| $K =$ | 5 |
| $\chi^2 =$ | 3.841 |
| Result $=$ | Reject $H_0$ |

Maximum Score = 6.

$\chi^2$ is the chi square statistic with 1 degree of freedom
and an $\alpha$ of 0.05.

**Figure 4.24. Kruskal-Wallis Test Comparing
Use of Measures to Compete on Basis of Any Edge:
DDPMS vs. DDPMS (Ideal)
(Lower Management Levels)**

**TOC (if scores were perfect)**

| Measure | Score | Rank |
|---|---|---|
| Throughput | 10 | 10.5 |
| Inventory | 10 | 10.5 |
| Operating Expense | 10 | 10.5 |
| Throughput Dollar Days | 10 | 10.5 |
| Inventory Dollar Days | 10 | 10.5 |
| Inventory Turnover | 10 | 10.5 |
| Net Profit | 10 | 10.5 |

$R_1 = 73.5$

**TOC**

| Measure | Score | Rank |
|---|---|---|
| Throughput | 9 | 6 |
| Inventory | 6 | 4 |
| Operating Expense | 10 | 10.5 |
| Throughput Dollar Days | 0 | 1.5 |
| Inventory Dollar Days | 0 | 1.5 |
| Inventory Turnover | 5 | 3 |
| Net Profit | 8 | 5 |

$R_2 = 31.5$

| | |
|---|---|
| $N =$ | 14 |
| $n =$ | 7 |
| $K =$ | 7.2 |
| $\chi 2 =$ | 3.841 |
| Result = | Reject $H_0$ |

Maximum Score = 10.

$\chi^2$ is the chi square statistic with 1 degree of freedom
and an $\alpha$ of 0.05.

**Figure 4.25. Kruskal-Wallis Test Comparing
Use of Measures to Compete on Basis of Any Edge:
TOC (Ideal) vs. TOC
(All Management Levels)**

**TOC (if scores were perfect)**

| Measure | Score | Rank |
|---|---|---|
| Throughput | 4 | 10.5 |
| Inventory | 4 | 10.5 |
| Operating Expense | 4 | 10.5 |
| Throughput Dollar Days | 4 | 10.5 |
| Inventory Dollar Days | 4 | 10.5 |
| Inventory Turnover | 4 | 10.5 |
| Net Profit | 4 | 10.5 |

$R_1 = 73.5$

**TOC**

| Measure | Score | Rank |
|---|---|---|
| Throughput | 3 | 5 |
| Inventory | 2 | 3 |
| Operating Expense | 4 | 10.5 |
| Throughput Dollar Days | 0 | 1.5 |
| Inventory Dollar Days | 0 | 1.5 |
| Inventory Turnover | 3 | 5 |
| Net Profit | 3 | 5 |

$R_2 = 31.5$

| | |
|---|---|
| $N =$ | 14 |
| $n =$ | 7 |
| $K =$ | 7.2 |
| $\chi^2 =$ | 3.841 |
| Result = | Reject $H_0$ |

Maximum Score = 4.
$\chi^2$ is the chi square statistic with 1 degree of freedom
and an $\alpha$ of 0.05.

**Figure 4.26. Kruskal-Wallis Test Comparing
Use of Measures to Compete on Basis of Any Edge:
TOC (Ideal) vs. TOC
(Upper Management Levels)**

**TOC (if scores were perfect)**

| Measure | Score | Rank |
|---|---|---|
| Throughput | 6 | 10 |
| Inventory | 6 | 10 |
| Operating Expense | 6 | 10 |
| Throughput Dollar Days | 6 | 10 |
| Inventory Dollar Days | 6 | 10 |
| Inventory Turnover | 6 | 10 |
| Net Profit | 6 | 10 |

$$R_1 = 70$$

**TOC**

| Measure | Score | Rank |
|---|---|---|
| Throughput | 6 | 10 |
| Inventory | 4 | 4 |
| Operating Expense | 6. | 10 |
| Throughput Dollar Days | 0 | 1.5 |
| Inventory Dollar Days | 0 | 1.5 |
| Inventory Turnover | 2 | 3 |
| Net Profit | 5 | 5 |

$$R_2 = 35$$

| | |
|---|---|
| $N =$ | 14 |
| $n =$ | 7 |
| $K =$ | 5 |
| $\chi 2 =$ | 3.841 |
| Result = | Reject $H_o$ |

Maximum Score = 6.

$\chi^2$ is the chi square statistic with 1 degree of freedom
and an $\alpha$ of 0.05.

**Figure 4.27. Kruskal-Wallis Test Comparing
Use of Measures to Compete on Basis of Any Edge:
TOC (Ideal) vs. TOC
(Lower Management Levels)**

Figure 4.28 shows any data the managers said they collected and the number of times each source was mentioned.

Managers could have cited the same data source for each competitive edge. Therefore, the maximum theoretical score for frequency was 30 (all ten managers using the same data for all three competitive edges). The highest scorers were "Adherence to schedule" for DDPMS and TOC, "Dollar amount," "Amount of inventory," and "Dollar amount for operating expense" for TOC.

Eleven sources of data were mentioned only once and six were mentioned only twice. These scores indicate a lack of consistency where managers find data to indicate performance in either measurement system. Figure 4.28 shows that managers use four sources most heavily but draw upon numerous other sources.

Content Analysis of Investigative Question #5. To make sense of the varied answers managers gave when answering this question (Which set of measures is being used to drive depot performance and why?), content analysis was again employed. This time, the categories were themes. For instance, one manager said, "DDPMS scares me." This comment was counted under the theme, "Negative comments about DDPMS." In addition to the comments made while answering investigative question #5, general comments about either set of measures offered during other parts of the interviews

## DDPMS

| Data Collected: | Frequency |
|---|---|
| Ultimate price to the customer | 2 |
| Cost of material | 1 |
| Cost per flying hour | 1 |
| Operating expense | 3 |
| Pipeline inventory levels | 1 |
| Loss of customer | 1 |
| MISTR (Management of Items Subject to Repair) workload | 1 |
| Lost opportunity | 1 |
| Peer reviews as items go through process | 1 |
| Utilization per man hour | 7 |
| Scrap and/or rework data | 4 |
| Adherence to schedule | 13 |
| QDR/MDR (customer feedback on quality) | 6 |
| Cost of educating for quality | 2 |
| Sales | 2 |
| Cost in general | 2 |

## TOC

| Data Collected | Frequency |
|---|---|
| Number of sales | 2 |
| Cost of materials | 4 |
| Adherence to schedule | 12 |
| Revenue data | 4 |
| Cost data | 4 |
| Cost of inventory | 2 |
| Work-in-process levels | 1 |
| Amount of inventory | 10 |
| Program budget dollars | 1 |
| Direct labor utilization | 2 |
| Dollar amount for operating expense | 17 |
| Inventory turnover | 1 |
| Scrap and rework | 1 |
| Production figures | 5 |
| QDR/MDR (customer feedback on quality) | 4 |

(Maximum Frequency = 30)

**Figure 4.28. Data Managers Collect for the Measures with Respect to the Competitive Edges**

were tabulated. Figure 4.29 shows the results of this content analysis.

There was no maximum number for some of the comments. For these, a separate, discrete comment was scored as one point in the Frequency column. For instance, one manager could have several positive comments about DDPMS. So long as the comments were different, they were counted. Other comments had a maximum of 10. For instance, a manager could state that a set of measures was superior only once. The "Maximum" column shows which comments could be mentioned any number of times and which were limited to ten.

Some of the more telling comments managers offered were: "TOC may have improved the process without understanding or defining those processes," and: "There are no definitions of TOC at the lower levels." Both of those comments came from branch managers. One manager berated DDPMS measures as the "old way of thinking," while another said, "DDPMS measures are more meaningful." A division manager said of DDPMS, "Measures of efficiency are poor at best."

Many of the managers believed that TOC was better, but that a combination of both kinds of measurements was still necessary. One of the most positive comments about TOC came from a branch manager who stated, "TOC makes sense toward understanding and reaching ALC's goals." Some managers noted that there was a shift away from the efficiency and cost accounting measures and toward TOC. However, one man-

| Themes: Responses to IQ #5 and Miscellaneous Comments | Frequency | Maximum Possible |
|---|---|---|
| Negative comments about TOC | 0 | No Limit |
| Positive comments about TOC | 5 | No Limit |
| Negative comments about DDPMS | 5 | No Limit |
| Positive comments about DDPMS | 1 | No Limit |
| Belief that TOC is superior | 4 | 10 |
| Belief that DDPMS is superior | 1 | 10 |
| Belief that ALC is moving toward TOC | 4 | 10 |
| Belief that ALC is moving toward DDPMS | 0 | 10 |
| Belief that both systems have merit | 1 | 10 |
| Belief that neither system has merit | 0 | 10 |
| Comments about TOC needing modifications | 3 | No Limit |
| Comments about DDPMS needing modifications | 0 | No Limit |
| Belief that they are using parts of each system | 7 | 10 |

(Comments from Ten Managers)

**Figure 4.29. Content Analysis of Answers to Investigative Question #5**

**(Which set of measures is being used to drive depot performance and why?)**

ager adamantly said that they were using a combination of both systems, and that they would <u>always</u> need to use a combination of both.

## Conclusion

Nonparametric testing revealed that, in all but one case, there was no significant difference between TOC and DDPMS. Only one Kruskal-Wallis test out of 26 resulted in a rejection of the null hypothesis, with the sign test pointing to TOC as the better system (as defined by the sign test) with respect to cost. Thus, the tests could not conclusively show whether one measurement system was being used more than another.

Content analysis showed which data managers collect to tell them how they are performing with respect to the competitive edges. Further, content analysis provided information about what managers thought about the two systems. TOC was viewed more favorably than DDPMS, perhaps because that is the system that the major command is currently pushing. Though managers said they preferred the TOC way of thinking, they still used DDPMS-type measures to gauge how well they were performing. The strongest indicator of preference was that seven of ten managers believed that they were using parts of both systems.

In contrast, the nonparametric tests showed that the managers were not using <u>either</u> measurement system to any

great degree.  Therefore, neither measurement system as a whole can be considered successful in helping managers compete, although certain measures within each are useful.  The next chapter will cover conclusions, recommendations, and suggestions for further research.

# V: Conclusions and Recommendations

## Introduction

This chapter presents the conclusions of the research, outlines recommendations, and offers suggestions for further research. First, conclusions are further elaborated, and the deficiencies in both systems are identified. Next, recommendations for improving performance measurement at Air Force depots are provided. Finally, suggestions for follow-on research in this subject matter are presented.

## Conclusions to the Investigative Questions

The following conclusions were reached by answering the investigative questions first posed in Chapter 1.

**Investigative Question #1.** What comprises competitiveness in the depot maintenance environment?

**Conclusion #1. Thorough research of the current literature shows that three main factors -- quality, delivery, and cost -- are the chief ways in which firms increase their competitive advantage in the marketplace. The research also indicates that these same competitive edges apply to Air Force depots, and that depot supervisors themselves have identified these edges as most important.**

A performance measurement system based on these competitive edges would encourage behavior to maximize the air logistics centers' ability to compete with civilian companies and other Service depots for work load. Because

these three factors are so predominant in the civilian literature and because depots need to compete, the authors used quality, delivery, and cost as the basis for the remainder of the research.

Investigative Question #2. How do the DDPMS and TOC measurements relate to each other?

Conclusion #2. **The survey of the literature showed that the two systems are markedly different.** DDPMS measures are based on efficiency. In addition, in an effort to create a system that would apply to all Service depots, many of the measures are highly aggregated and represent ratios of what the depot planned to do versus what it actually did. Conversely, the TOC measures are based on the idea of finding the organization's constraints and exploiting them to gain advantage. The primary measures of Throughput, Inventory, and Operating Expense are quantifiable tools that managers can use to reach their goals.

Investigative Question #3. Do DDPMS measures provide proper information to meet objectives whereby depot management can improve processes to compete on quality, delivery, and cost?

Conclusion #3. **Based on the research, it is clear that DDPMS, as a whole, provides very little information to meet objectives whereby depot management can improve processes to compete on quality, delivery, and cost.** However, two constituent measures, Schedule Conformance and Direct

Labor Utilization, were useful in helping managers compete on delivery and cost, respectively.

Because the measurement systems are so different, a test was devised to compare them not directly to each other, but to how useful depot managers thought the sets of measures were with respect to quality, delivery, and cost. (See Appendix A for the list of interview questions and Chapter IV for the complete test results.)

The analysis showed that many managers were completely unfamiliar with DDPMS and were unaware of its existence. They were, however, familiar with some of the constituent measures, which are based on cost accounting measures that had been used in the depots for years.

DDPMS measures were judged by the depot managers as not relating well to quality as a competitive edge. The measure that received the highest score, Schedule Conformance, was considered useful by only half of the ten managers. Obviously, Schedule Conformance is not a measure of quality, and the fact that managers are trying to use it as such indicates how inadequately DDPMS drives performance with respect to quality. Additionally, the measure one would expect to relate to quality, Cost of Quality, scored worse than Schedule Conformance (three of the ten managers said COQ was useful for quality).

DDPMS fared somewhat better with respect to delivery. Schedule Conformance scored a perfect ten out of ten, mean-

ing that all the managers agreed that this measure was useful in helping them compete on delivery. However, none of the other measures scored over five. These results show that only one of the ten DDPMS measures relates to delivery. Further, that measure (Schedule Conformance) addresses only one aspect of delivery, that of meeting the scheduled delivery date. The ability to deliver quicker than the competition -- "shorter quoted lead time" -- is not even considered in DDPMS.

On the basis of cost, DDPMS has only one measure that scored higher than four: Direct Labor Utilization (DLU). Seven of the ten managers said they used DLU to determine how well they were performing with respect to cost. However, as a whole, DDPMS measures provide very few measures that relate to cost as a competitive edge.

Investigative Question #4. To what extent do TOC measures provide information that depot management can use to improve processes to compete on quality, delivery, and cost?

Conclusion #4. **Based on the research, the TOC-based measures as a whole do not relate well to the competitive edges.** However, the research did demonstrate that managers found certain TOC measures -- Throughput, Operating Expense, and Net Profit -- useful for providing information to meet objectives whereby they could improve processes to compete on delivery and cost.

For quality, the only measure that scored above a three was Throughput, with a score of five out of ten. This is obviously a very indirect measure of quality, which gives some indication of how little TOC provides information to improve competitiveness on the basis of quality.

With respect to delivery, the only TOC measure considered useful by more than five managers was Throughput, which scored seven out of ten. Unfortunately the managers did not understand the secondary measure Throughput Dollar Days (TDD), which would provide useful information to help depot managers compete on the basis of delivery (see Recommendations below).

TOC fared quite well with respect to cost. Three measures -- Throughput, Operating Expense, and Net Profit -- score seven or higher. In fact, cost was the only competitive edge in which one system tested as more useful than the other. TOC scored significantly better than DDPMS. This is ironic, since DDPMS measures are cost-based, efficiency measures. This is not to say that either measurement system as a whole is better than the other. When quality, delivery, and cost were aggregated together, the statistical tests showed no significant difference between DDPMS and TOC.

Investigative Question #5. Which set of measures is being used to drive depot performance and why?

Conclusion #5. **The analysis of the measures currently used in Air Force depots points out that neither system provides measures that help managers compete on quality, delivery, and cost.** Therefore, managers are using neither system as a whole. It is worth noting that while neither _system_ is being fully used, parts of each system are. Measures that eight or more managers used to compete on either quality, delivery, or cost included Schedule Conformance, Direct Labor Utilization (both DDPMS measures), Throughput, Operating Expense, and Net Profit (all TOC measures).

It is important to reiterate that these competitive edges were not chosen at random. The literature review (Chapter II) clearly shows that these three factors are crucial for competition. Kwolek's research also indicated that depot managers consider these factors to be the most important in meeting the challenge of competition. Yet this study shows that both measurement systems do a poor job in driving behavior that would improve depot performance with respect to quality, delivery, and cost.

Managers used Schedule Conformance and Direct Labor Utilization because they are still rated according to these standards. However, many of them simply liked the measures because they thought they were easy to understand and told them what they believed they needed to know.

## Other Conclusions

Conclusion #6. **Only some of the measures were used and understood.** Under DDPMS, three of the seven measures were considered useful by over half of the ten managers for at least one of the competitive edges. Under TOC, four of the seven measures were considered useful by over half of the ten managers for at least one of the competitive edges.

It is apparent from the data that significant gaps of understanding exist in the measures based on the Theory of Constraints (TOC) and the Defense Depot Performance Measurement System (DDPMS). Peacetime Utilization Index, Productivity Index, and Productivity Index (under DDPMS) were poorly understood. Under TOC, Throughput Dollar Days and Inventory Dollar Days received low scores in measurement understanding.

Among depot managers, understanding of the primary TOC measures was excellent. Most managers owned a copy of The Goal and had attended ALC classes in TOC. The level of education indicates that the managers were acquainted with the basics of the Theory of Constraints (i.e., they understood Throughput, Inventory, and Operating Expense). However, they did not understand some of the derived measures, like Throughput Dollar Days and Inventory Dollar Days, which could provide them with information that line supervisors might find useful.

Many managers had misgivings about the usefulness of Inventory as a measure in the depot environment. Some stated that they had no effective way to measure their inventory. Others claimed to have little or no control over the size of their inventory. One manager explained, "The end items don't belong to us." An upper-level manager said that the measure "needs work" for their purposes, that it would have to combine material on the floor, equipment, and facilities. One manager involved with software had difficulty relating the TOC definition of Inventory to his branch. "In software, it's hard to define," and explained that he treats the money allocated to a given project as "inventory." As that money is expended toward the project, Inventory is converted into Throughput.

Some measures were understood but not used. For instance, some managers said that data systems were not in place to give them accurate and timely inventory numbers. Most said they would like to use Cost of Quality data, yet no system existed that would give them reliable figures for scrap and rework. Other measures were well understood, but not considered to be useful. For instance, while a large percentage of managers understood the concept of innovation and thought it was necessary for enhancing a depot's ability to compete, they could see no way to measure it accurately.

Conclusion #7. **Managers questioned the applicability of TOC.** One of the problems with TOC is the obvious differ-

ence between manufacturing and depot repair. In manufacturing, managers can set firm schedules; they know what parts will be required to assemble products, and they know how much time that assembly will take. However, in maintenance, the number of items that will arrive at a depot in any given period varies. Moreover, the degree of repair that any item will need varies. Some items that cycle through the depot system always require the same steps to be performed. If the part fails, it is completely overhauled or scrapped. Conversely, other items require a wide array of possible maintenance actions, ranging from a simple adjustment and bench check to hours of troubleshooting leading to a complete overhaul. Many managers said that TOC needed modification to account for the wide statistical variation in time and parts required for repair.

Conclusion #8. **Neither system measures performance in quality.** Both measurement systems are especially lacking in giving managers help with respect to quality. No measure in either system received a score over five. This is a startling discovery, since quality is arguably the most important factor of competition. Certainly, if the amount of literature published over the past 15 years is the criterion, quality is the most important competitive edge.

Ironically, on 27 January 1992, the AFLC (now AFMC) Performance Measurement Committee decided that in the TOC measurement system, quality would be considered a "necessary

condition." In other words, if quality is poor, then Throughput will decrease, Inventory will likely increase, and Operating Expense will rise (AFLC/LGPP, 1992(b)).

Goldratt explains that a necessary condition is an externally imposed constraint on an organization's behavior. Organizations must endeavor to meet their goals within these constraints. The minimum level of quality imposed by the customer is one such necessary condition. He says:

> For an industrial enterprise, clients are definitely a power group. They do impose necessary conditions like a minimum level of customer service and a minimum level of product quality. If these minimum conditions are not met, the clients will simply stop purchasing from the organization, and it will face extinction. (Goldratt, 1990:11)

While all this may be true, quality still needs to be measured. A "necessary condition" does not mean it is a "given." On the contrary, if poor quality manifests itself in negative effects in T, I, and OE, then some measurement or group of measurements could give managers some idea as to their depot's performance with respect to quality. Waiting for a drop in Throughput to signal a root problem in quality is waiting too long. In today's competitive market, the first indication of poor quality may just well be the loss of the customer. QDRs and MDRs, as discussed in Chapter II, have little utility for addressing root problems in quality. Further, depot inspections cannot be relied upon to find all quality discrepancies. Cost of quality is an attempt to quantify the impact of poor quality, but simply measuring

scrap and rework will not in and of itself induce quality improvement.

Recommendations

Recommendation #1. **Implement quality measures that are more useful.** Neither the DDPMS nor the TOC-based measures guide managers in quality performance. As previously stated in Chapter II, the preponderance of the literature agreed that quality is one of the most important factors of competition. Using measures like Throughput as indirect indicators of quality is ill advised. Reducing the number of defects (while concurrently reducing cycle time) is a useful and proven method for improving quality and delivery at the same time.

One method that has proved itself in private corporations (Motorola and IBM, for example) is a program to reduce both cycle time and defects simultaneously (Emmelhainz, 1991:35). An organization can easily reduce the number of errors by slowing down the work cycle per item and doing a more painstaking job. By the same token, a firm can reduce its cycle time (in the depot's case, from the point when an item is sent from the customer until the customer gets the repaired item back), by simply speeding up the processes. Unfortunately, this acceleration usually leads to a higher number of defects.

The key, then, is to reduce the cycle time without sacrificing quality and to increase the level of quality without slowing down the delivery to the customer. An awareness of the goal to reduce cycle time and defects will drive managers and workers to improve processes that will fulfill these objectives. In fact, measures to track performance in cycle time and defects would be even more effective.

A shorter cycle time means that the item will be delivered to the customer sooner. Although DDPMS puts no value on early delivery to the customer, delivery ahead of schedule (shorter quoted lead time) is a dramatic way in which an organization can set itself apart from the competition. In addition, shorter cycle times result in less inventory of spares -- an important point in this time of decreasing budgets. A firm that can bid for depot maintenance work load promising highest quality and the shortest item turnaround time would clearly enjoy a significant advantage over its competitors. Unfortunately, the mind set at the depot level still seems to be to "meet the schedule." No manager who was interviewed ever said that early delivery was desirable or even contemplated.

Recommendation #2. **Combine the best of both systems.** A new system of measures should contain the best of DDPMS and TOC measures as well as some useful quality measures. The DDMC should consider all performance measures and choose those that drive depot performance to compete favorably with

private firms and other military depots along the lines of quality, delivery, and cost. A good measurement system, one that drives managers to improve on these competitive edges, would take the best of both measurement systems and add new measures that are currently lacking in both.

A suggested measurement system would include Schedule Conformance, Direct Labor Utilization, Throughput, Inventory, Operating Expense, and Net Profit. TOC purists will argue that DLU is in direct conflict with the Theory of Constraints, because it is an efficiency measure. However, as long as managers understand that the goal is not simply to maximize utilization in all parts of the system, but to maximize the utilization at the constraint, then DLU and TOC can coexist. This research clearly indicates that DLU gives lower level managers important information about their costs and how their people are being used.

Also, Inventory Dollar Days and Throughput Dollar Days would provide managers with useful information on how to compete on cost and delivery, respectively. Finally, a program emphasizing the reduction of cycle time and defects would help depots make great strides in competing on the bases of delivery and quality.

Recommendation #3. **Insure better education.** Both measurement systems are relatively new, so it is reasonable to expect incomplete understanding and use of the measures. However, a surprising number of managers had never heard of

the Defense Depot Performance Measurement System. In addition, six months after the January AFLC Performance Measurement Committee meeting, nine out of ten managers could define neither Throughput Dollar Days nor Inventory Dollar Days. From their reactions, it was clear that they had never even heard the terms before. A lag between headquarters and the field is to be expected, but this lack of familiarity indicates a less-than-adequate method of disseminating information. While this study did not review causes of this delay, such lag times are absolutely unacceptable in a competitive environment.

Recommendation #4. **Change the policy on net profit.** Some managers expressed dismay that, even though they had improved their processes and lowered their overall costs, they could not pass on those cost savings to the customer. The reason was that some areas of the depot were "in the red," and their costs were much higher than their revenues. Funds from units operating at a positive net profit were transferred to those operating at a net loss to make up the difference.

Branches that turn a profit should not have to cover for other units that are losing money. The only way to survive is to satisfy the customer. Cost is a main competitive edge. Cutting costs will enable depots to survive and attract more business. If a section cannot provide a service

at a competitive price, then it should face the risks of not being competitive.

As far as performance measurement goes, the practice of transferring profit will stifle initiative and innovation. If a manager and his or her employees can improve the way they conduct business insofar as they reduce the overall cost of repairing an item, they will naturally want to lower the price to the customer as a kind of tangible reward. Under current practices, though, nothing changes. The system offers little incentive for industrious, enterprising branches. Allowing managers to cut prices will increase incentive to improve processes while making the branch more competitive.

Recommendation #5. **Base the depot performance measurement system on the factors of competition.** The authors recommend that any new system to measure depot performance should proceed from the question, "How can we improve our competitive position with respect to quality, delivery, and cost?" If the ultimate goal of a depot is to remain in business and obtain greater work load, then it will have to compete with other depots and private firms to provide the highest quality and the most reliable delivery at the best price. The measures in Recommendation 2 relate to these three edges as shown in Figure 5.1.

| Factor | Measures |
|---|---|
| Quality | Defects |
| Delivery<br>    On time<br><br><br>    Shorter quoted lead time | Schedule Conformance<br>Throughput*<br>Throughput Dollar Days*<br>Cycle Time |
| Cost | Inventory*<br>Inventory Dollar Days*<br>Operating Expense*<br>Net Profit*<br>Direct Labor Utilization<br>    (only at the constraint) |

*as defined by the Theory of Constraints

**Figure 5.1: How the Competitive Edges Relate to
the Proposed Measures**

Measuring the number of defects, especially with respect to the number of units produced, is an effective way of measuring quality. A unit could be considered an aircraft, an exchangeable item, etc. The goal is to reduce the number of defects without increasing the cycle time of the item. Cycle time relates to delivery, in that reducing the item's cycle time enables an organization to deliver the item quicker than the competition (shorter quoted lead time). A related benefit of reducing cycle time and defects (or defects per unit) is that it drives down cost (Emmelhainz, 1991:35-37).

Schedule Conformance is another useful delivery measure. It encourages effective planning in delivering items to customers (DDMC, 1990:17). One alteration is needed to

the strict DDPMS definition of Schedule Conformance. The measure should allow and even encourage early delivery, because being able to quote and fulfill shorter lead times to customers is a powerful competitive advantage.

The next measurement that relates to delivery is Throughput. Throughput is defined as "the rate at which the system generates money through sales" (Goldratt and Fox, 1986:29). The objective is to increase Throughput. The increased rate of sales is directly related to delivery of the finished product. This measure is useful, because an item is only counted as Throughput when it is finally delivered to the customer. Until then, the item is considered Inventory that is costing the organization money. (See explanation of the Inventory measure below.)

Another useful delivery measure is Throughput Dollar Days. This is the value of the order multiplied by the number of days late (AFLC/LGPP, 1992(a):3-4). This measure gives a clear indication of the impact of not delivering on time and encourages the organization to convert Inventory into Throughput.

Several measures are useful for competing on the basis of cost. First, Inventory is a direct way of measuring cost, since it is defined as "all the money the system invests in purchasing things the system intends to sell" (Goldratt and Fox, 1986:29). If the main reason for the depots' existence is to deliver repaired items to their cus-

tomers as soon as possible, then the objective to reduce Inventory is beneficial, because it drives managers to deliver repaired items to the customer expeditiously. That is to say, there is a great incentive to convert Inventory into Throughput. Also, the Inventory measure encourages managers to eliminate inapplicable inventory (items that will never be converted into Throughput).

The next cost measure is Inventory Dollar Days (IDD). AFMC has defined the measure as "the sum of the daily value of inventory," but Goldratt and Fox's definition is clearer. They define the measure as the value of the order multiplied by the number of days until sold, i.e., until it is converted into Throughput. IDD is a useful measure, since it causes managers to "concentrate on reducing . . . those inventories that are in the plant's possession for an extended period" (Goldratt and Fox, 1988:20).

Operating Expense is another useful cost indicator. It is defined as, "all the money the system spends in turning inventory into throughput" (Goldratt and Fox, 1986:29). This is an obvious measure for helping managers compete with respect to cost.

The next cost measure is Net Profit, which is defined as the difference between Throughput and Operating Expense (AFLC/LGPP, 1992:3-4). If organizations can increase Throughput without increasing Operating Expense, the

"bottom-line measure" of Net Profit will increase (Goldratt and Fox, 1986:30).

Finally, Direct Labor Utilization (DLU) is a useful cost measure , because it gives managers a direct indication of the labor assigned and charged to a specific job (DDMC, 1990:19). However, the goal of 100 percent utilization in the entire organization needs to be changed to 100 percent utilization only at the constraint. Any effort to maximize DLU elsewhere does not contribute to Throughput and is, therefore, wasted (Goldratt and Fox, 1986:28).

## Suggested Further Research

Whether the new system proposed in this study is adopted or not, research should continue to discover how the measures used in the depot environment drive competitiveness. The same test instrument employed in this study could be used as the basis for a survey, which would allow a larger sample to be tested. The larger sample would increase confidence in test results, since parametric statistics would be applicable. There is a tradeoff associated with replacing the interviews with a survey. The authors of this study learned a great deal by talking candidly with the depot managers. This benefit would be lost if a survey were conducted.

The next step would be to test other depots, perhaps comparing one against another, to see if the disconnect be-

tween performance measures and competitiveness is pervasive throughout the depot maintenance arena. Researchers could employ a survey or use the same methodology used in this study. The proposed measures could then be tested in a comparable setting, comparing them to the sets of measures used in a "pure" DDPMS system and a "pure" TOC system. These tests will indicate how well each system compares to the other.

If future results continue to show that neither DDPMS nor TOC promotes competitiveness, the ALCs might consider adopting the measurement system recommended by the authors, or at least some new system based on the competitive edges. The next logical step would be to test the proposed new system.

Future researchers should take care to avoid the pitfalls the authors fell into. Unfortunately, the definitions taken for the Cost of Quality were too generous. Some managers defined it as more like nonconformance/conformance, while others defined it as the total amount invested in quality. Part of the problem is in the confusing definitions DDPMS offers for its quality measures. In any case, future researchers should be more rigid in the definitions they accept as correct for this measure.

## Summary

The premise of this thesis was that performance measures should drive behavior to enhance an organization's competitive advantage. The current literature revealed that the primary ways in which firms can create a competitive advantage are to focus on improving performance in the areas of quality, delivery and cost. Two Air Force depot maintenance performance measurement systems, DDPMS and TOC, were investigated to discover which (if either) system was better in giving managers the information they needed to compete.

This study showed that neither system was being used to any significant degree but that some measures within both systems were understood and used. The study also revealed a lack of measures that would drive improvement on the basis of quality. A combination of the most useful measures from both systems with the additional measures of cycle time and defects to address delivery and quality was also recommended. Further, it was recommended that the command institute a more effective process to educate their managers about performance measurement. Next, the authors recommended eliminating the practice of redistributing net profit from subunits that are making money to those who are losing money. Finally, the authors recommended that any new measurement system that either the DoD or AFMC adopts should be founded on the principle that performance measures must drive behavior to increase a depot's competitive position.

This thesis started with the premise that depot maintenance is becoming more competitive. The DDMC stated that their system, DDPMS, would provide information that would play a role in the distribution of workload among all defense depots. Therefore, depots in all branches of the DoD are now competing against one another. In addition, private firms are beginning to compete for workload in the repair of exchangeable items.

Faced with this threat, Air Force depots must compete or lose business to military and civilian competitors. The question "How to compete?" is answered by three words: quality, delivery, and cost. If depots wish to stay viable, they must provide the highest quality and the most reliable delivery at the best price.

This study has revealed that both measurement systems currently in are unlikely to help Air Force depots improve competitiveness since they do not relate to the three key aspects of quality, delivery, and cost. Without performance measurement tools to meet the competition, managers are operating in the dark. The end result will be lost workload, downsizing, and possible eventual closure.

The authors, through the interviews with management, found that the managers at all levels were highly interested in performing better. They were proud of their work and believed that, if given the proper tools, they can compete and

win. Providing them with more useful performance measures will increase their chances of doing so.

## Appendix A: Interview Questions

**Questions to Ask Managers**.          Competitive Edge:  Cost.

Schedule Conformance vs. cost.

1.  How would you define this measure?

2.  Do you use Schedule Conformance to determine how well you are performing with respect to cost?

      a.  If yes, how?

      b.  If you don't, why not?

3.  What data do you collect for this measure with respect to cost?

**Questions to Ask Managers**.          Competitive Edge:  Cost.

Direct Labor Utilization vs. cost.

1.  How would you define this measure?

2.  Do you use Direct Labor Utilization to determine how well you are performing with respect to cost?

      a.  If yes, how?

      b.  If not, why not?

3.  What data do you collect for this measure with respect to cost?

**Questions to Ask Managers**.          Competitive Edge:   Cost.

Cost of Quality vs. cost.

1.  How would you define this measure?

2.  Do you use Cost of Quality to determine how well you are performing with respect to cost?

a.   If yes, how?

b.   If not, why not?

3.   What data do you collect for this measure with respect to cost?

**Questions to Ask Managers**.             Competitive Edge:  Cost.

Peacetime Utilization Index vs. cost.

1.   How would you define this measure?

2.   Do you use Peacetime Utilization Index to determine how well you are performing with respect to cost?

   a.   If yes, how?

   b.   If not, why not?

3.   What data do you collect for this measure with respect to cost?

**Questions to Ask Managers.**        Competitive Edge:  Cost.

Productivity Index vs. cost.

    1.  How would you define this measure?

    2.  Do you use Productivity Index to determine how well you are performing with respect to cost?

        a.  If yes, how?

        b.  If not, why not?

    3.  What data do you collect for this measure with respect to cost?

**Questions to Ask Managers**.          Competitive Edge:  Cost.

Cost Performance Index vs. cost.

1.   How would you define this measure?

2.   Do you use Cost Performance Index to determine how
well you are performing with respect to cost?

     a.   If yes, how?

     b.   If not, why not?

3.   What data do you collect for this measure with
respect to cost?

**Questions to Ask Managers**.                    Competitive Edge:   Cost.

Innovation vs. cost.

1.   How would you define this measure?

2.   Do you use Innovation to determine how well you are performing with respect to cost?

        a.   If yes, how?

        b.   If not, why not?

3.   What data do you collect for this measure with respect to cost?

**Questions to Ask Managers**.          Competitive Edge:   Cost.

Throughput vs. cost.

1.  How would you define this measure?

2.  Do you use Throughput to determine how well you are performing with respect to cost?

      a.  If yes, how?

      b.  If not, why not?

3.  What data do you collect for this measure with respect to cost?

**Questions to Ask Managers**.          Competitive Edge: Cost.

Inventory vs. cost.

1. How would you define this measure?

2. Do you use Inventory to determine how well you are performing with respect to cost?

    a. If yes, how?

    b. If not, why not?

3. What data do you collect for this measure with respect to cost?

**Questions to Ask Managers.**          Competitive Edge:  Cost.

Operating Expense vs. cost.

1.  How would you define this measure?

2.  Do you use Operating Expense to determine how well you are performing with respect to cost?

      a.  If yes, how?

      b.  If not, why not?

3.  What data do you collect for this measure with respect to cost?

**Questions to Ask Managers**.          Competitive Edge:  Cost.

Throughput Dollar Days vs. cost.

1.  How would you define this measure?

2.  Do you use Throughput Dollar Days to determine how well you are performing with respect to cost?

       a.  If yes, how?

       b.  If not, why not?

3.  What data do you collect for this measure with respect to cost?

**Questions to Ask Managers**.        Competitive Edge:  Cost.

Inventory Dollar Days vs. cost.

1.  How would you define this measure?

2.   Do you use Inventory Dollar Days to determine how well you are performing with respect to cost?

   a.  If yes, how?

   b.  If not, why not?

3.   What data do you collect for this measure with respect to cost?

**Questions to Ask Managers**.          <u>Competitive Edge:  Cost</u>.

<u>Inventory Turnover vs. cost.</u>

1.  How would you define this measure?

2.  Do you use Inventory Turnover to determine how well you are performing with respect to cost?

      a.  If yes, how?

      b.  If not, why not?

3.  What data do you collect for this measure with respect to cost?

**Questions to Ask Managers.**     <u>Competitive Edge:   Cost</u>.

   <u>Net Profit vs. cost.</u>

   1.   How would you define this measure?

   2.   Do you use Net Profit to determine how well you are
performing with respect to cost?

        a.   If yes, how?

        b.   If not, why not?

   3.   What data do you collect for this measure with
respect to cost?

**Questions to Ask Managers.**          Competitive Edge:  Quality

Schedule Conformance vs. quality.

    1.  How would you define this measure?

    2.  Do you use Schedule Conformance to determine how well you are performing with respect to quality?

        a.  If yes, how?

        b.  If not, why not?

    3.  What data do you collect for this measure with respect to quality?

Direct Labor Utilization vs. quality.

1.   How would you define this measure?

2.   Do you use Direct Labor Utilization to determine how well you are performing with respect to quality?

     a.   If yes, how?

     b.   If not, why not?

3.   What data do you collect for this measure with respect to quality?

**Questions to Ask Managers**.          Competitive Edge: Quality

Cost of Quality vs. quality.

1.   How would you define this measure?

2.   Do you use Cost of Quality to determine how well you
are performing with respect to quality?

        a.   If yes, how?

        b.   If not, why not?

3.   What data do you collect for this measure with
respect to quality?

**Questions to Ask Managers**.       Competitive Edge:   Quality

Peacetime Utilization Index vs. quality.

1. How would you define this measure?

2. Do you use Peacetime Utilization Index to determine how well you are performing with respect to quality?

   a. If yes, how?

   b. If not, why not?

3. What data do you collect for this measure with respect to quality?

**Questions to Ask Managers**.     <u>Competitive Edge:  Quality</u>

<u>Productivity Index vs. quality.</u>

1.  How would you define this measure?

2.  Do you use Productivity Index to determine how well you are performing with respect to quality?

    a.  If yes, how?

    b.  If not, why not?

3.  What data do you collect for this measure with respect to quality?

**Questions to Ask Managers**.       Competitive Edge:   Quality

Cost Performance Index vs. quality.

1.  How would you define this measure?

2.  Do you use Cost Performance Index to determine how well you are performing with respect to quality?

      a.  If yes, how?

      b.  If not, why not?

3.  What data do you collect for this measure with respect to quality?

**Questions to Ask Managers.**        Competitive Edge:  Quality

Innovation vs. quality.

1.    How would you define this measure?

2.    Do you use Innovation to determine how well you are
performing with respect to quality?

  a.    If yes, how?

  b.    If not, why not?

3.    What data do you collect for this measure with
respect to quality?

Throughput vs. quality.

1.  How would you define this measure?

2.  Do you use Throughput to determine how well you are performing with respect to quality?

    a.  If yes, how?

    b.  If not, why not?

3.  What data do you collect for this measure with respect to quality?

Inventory vs. quality.

1.  How would you define this measure?

2.  Do you use Inventory to determine how well you are performing with respect to quality?

        a.  If yes, how?

        b.  If not, why not?

3.  What data do you collect for this measure with respect to quality?

**Questions to Ask Managers**.        <u>Competitive Edge:  Quality</u>

<u>Operating Expense vs. quality.</u>

1.  How would you define this measure?




2.  Do you use Operating Expense to determine how well you are performing with respect to quality?

    a.  If yes, how?



    b.  If not, why not?



3.  What data do you collect for this measure with respect to quality?

**Questions to Ask Managers**.          Competitive Edge:  Quality

Throughput Dollar Days vs. quality.

1.   How would you define this measure?

2.   Do you use Throughput Dollar Days to determine how well you are performing with respect to quality?

   a.   If yes, how?

   b.   If not, why not?

3.   What data do you collect for this measure with respect to quality?

**Questions to Ask Managers.**        Competitive Edge:  Quality

Inventory Dollar Days vs. quality.

1.   How would you define this measure?

2.   Do you use Inventory Dollar Days to determine how well you are performing with respect to quality?

   a.  If yes, how?

   b.  If not, why not?

3.   What data do you collect for this measure with respect to quality?

**Questions to Ask Managers.**        Competitive Edge:  Quality

Inventory Turnover vs. quality.

1.   How would you define this measure?

2.   Do you use Inventory Turnover to determine how well
you are performing with respect to quality?

        a.   If yes, how?

        b.   If not, why not?

3.   What data do you collect for this measure with
respect to quality?

Net Profit vs. quality.

1.   How would you define this measure?

2.   Do you use Net Profit to determine how well you are performing with respect to quality?

        a.   If yes, how?

        b.   If not, why not?

3.   What data do you collect for this measure with respect to quality?

**Questions to Ask Managers**.        Competitive Edge:  Delivery.

Schedule Conformance vs. delivery.

1.  How would you define this measure?

2.  Do you use Schedule Conformance to determine how well you are performing with respect to delivery?

a.  If yes, how?

b.  If not, why not?

3.  What data do you collect for this measure with respect to delivery?

**Questions to Ask Managers**.        Competitive Edge:  Delivery.

<u>Direct Labor Utilization vs. delivery.</u>

1.  How would you define this measure?

2.  Do you use Direct Labor Utilization to determine how
well you are performing with respect to delivery?

      a.  If yes, how?

      b.  If not, why not?

3.  What data do you collect for this measure with
respect to delivery?

**Questions to Ask Managers**.       Competitive Edge:  Delivery.

Cost of Quality vs. delivery.

1.  How would you define this measure?

2.  Do you use Cost of Quality to determine how well you are performing with respect to delivery?

       a.  If yes, how?

       b.  If not, why not?

3.  What data do you collect for this measure with respect to delivery?

**Questions to Ask Managers**.      Competitive Edge:  Delivery.

Peacetime Utilization Index vs. delivery.

1.  How would you define this measure?

2.  Do you use Peacetime Utilization Index to determine
how well you are performing with respect to delivery?

      a.  If yes, how?

      b.  If not, why not?

3.  What data do you collect for this measure with
respect to delivery?

**Questions to Ask Managers**.        Competitive Edge:  Delivery.

Productivity Index vs. delivery.

1.  How would you define this measure?

2.  Do you use Productivity Index to determine how well you are performing with respect to delivery?

        a.  If yes, how?

        b.  If not, why not?

3.  What data do you collect for this measure with respect to delivery?

**Questions to Ask Managers**.        Competitive Edge:  Delivery.

Cost Performance Index vs. delivery.

1.  How would you define this measure?

2.  Do you use Cost Performance Index to determine how well you are performing with respect to delivery?

   a.  If yes, how?

   b.  If not, why not?

3.  What data do you collect for this measure with respect to delivery?

**Questions to Ask Managers**.          Competitive Edge:  Delivery.

Innovation vs. delivery.

1.   How would you define this measure?

2.   Do you use Innovation to determine how well you are performing with respect to delivery?

       a.   If yes, how?

       b.   If not, why not?

3.   What data do you collect for this measure with respect to delivery?

**Questions to Ask Managers.**    Competitive Edge:  Delivery.

Throughput vs. delivery.

1.  How would you define this measure?

2.  Do you use Throughput to determine how well you are
performing with respect to delivery?

       a.  If yes, how?

       b.  If not, why not?

3.  What data do you collect for this measure with
respect to delivery?

**Questions to Ask Managers**.        Competitive Edge:  Delivery.

Inventory vs. delivery.

1.  How would you define this measure?

2.  Do you use Inventory to determine how well you are performing with respect to delivery?

        a.  If yes, how?

        b.  If not, why not?

3.  What data do you collect for this measure with respect to delivery?

**Questions to Ask Managers.**    Competitive Edge:  Delivery.

Operating Expense vs. delivery.

1.  How would you define this measure?




2.  Do you use Operating Expense to determine how well
you are performing with respect to delivery?

    a.  If yes, how?



    b.  If not, why not?



3.  What data do you collect for this measure with
respect to delivery?

**Questions to Ask Managers**.          Competitive Edge:  Delivery.

Throughput Dollar Days vs. delivery.

1.  How would you define this measure?

2.  Do you use Throughput Dollar Days to determine how well you are performing with respect to delivery?

    a.  If yes, how?

    b.  If not, why not?

3.  What data do you collect for this measure with respect to delivery?

**Questions to Ask Managers**.       Competitive Edge:   Delivery.

Inventory Dollar Days vs. delivery.

1.   How would you define this measure?

2.   Do you use Inventory Dollar Days to determine how well you are performing with respect to delivery?

   a.   If yes, how?

   b.   If not, why not?

3.   What data do you collect for this measure with respect to delivery?

**Questions to Ask Managers**.    Competitive Edge:  Delivery.

Inventory Turnover vs. delivery.

1.  How would you define this measure?

2.  Do you use Inventory Turnover to determine how well you are performing with respect to delivery?

    a.  If yes, how?

    b.  If not, why not?

3.  What data do you collect for this measure with respect to delivery?

**Questions to Ask Managers.**      <u>Competitive Edge:   Delivery</u>.

   <u>Net Profit vs. delivery.</u>

   1.   How would you define this measure?

   2.   Do you use Net Profit to determine how well you are
performing with respect to delivery?

        a.   If yes, how?

        b.   If not, why not?

   3.   What data do you collect for this measure with
respect to delivery?

**Questions to Ask Managers**.

Last Question -- literally, Investigative Question #5:

Which set of measures [DDPMS or TOC] is being used to drive depot performance and why?

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## Vitae

Captain Jack A. Meyer, Jr., was born on 2 February 1962 in Geneva IL. He graduated from high school in 1980 and attended Lewis University in Romeoville IL. He graduated in 1984 with a Bachelor of Science Degree in Aviation Maintenance and Management and was selected to the dean's list. In October 1985, he married Mary Matysik. He earned his commission from Officer Training School in March 1986. Upon graduation from the Aircraft Maintenance Officer Course at Chanute AFB IL, he was assigned to the 93d Bombardment Wing, Castle AFB CA, Strategic Air Command. While assigned at Castle, he served as Assistant Maintenance Supervisor, 93d Field Maintenance Squadron; Assistant Maintenance Supervisor, 93d Avionics Maintenance Squadron; Officer in Charge, KC-135 Maintenance Branch, 693d Organization Maintenance Squadron; Maintenance Supervisor, 93d Avionics Maintenance Squadron, and Chief, Standardization and Training Branch, 93d Bombardment Wing. In 1990, he completed Squadron Officer School in residence. He entered the Air Force Institute of Technology School of Systems and Logistics in May 1991.

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Mr. Timothy A. Widowfield was born on 23 September 1959 in Salem OH. He graduated from high school in 1977 and attend Ohio University, Athens OH until 1979, when he enlisted in the Air Force. He served for four years as a Russian linguist in Berlin, West Germany, and then Ft. Meade MD. Upon separation he attended college at the University of Maryland at College Park. He graduated magna cum laude in December 1985 with a Bachelor of Arts Degree in History. He earned his commission from the Officer Training School in April 1986. After finishing Aircraft Maintenance Officer School in September 1986, he was assigned to the 9th Strategic Reconnaissance Wing, Beale AFB CA. There, he served as Assistant Maintenance Supervisor, 9th Field Maintenance Squadron; SR-71/U-2 Maintenance Officer, 9th Organizational Maintenance Squadron, and Chief, Programs and Mobility, 9th Strategic Reconnaissance Wing. In January 1989, he was selected to serve as Commander, Field Training Detachment 525, 3753d Field Training Squadron, Beale AFB CA, Air Training Command. He completed Squadron Officer School in March 1991. He enter the Air Force Institute of Technology School of Systems and Logistics in May 1991, and voluntarily separated from the Air Force on 11 August 1992.

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# REPORT DOCUMENTATION PAGE

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**13. ABSTRACT (Maximum 200 words)**

This thesis acknowledges that Air Force Materiel Command maintenance depots will face increased competition for workload, especially exchangeable items, both from other Service depots and from civilian contractors. The authors, through the literature review, identify quality, delivery, and cost as the three primary competitive edges firms can use to gain advantage in the marketplace. Further, a recent study confirms that Air Force depot managers also consider these three factors of competitiveness to be most important. The authors tested two depot measurement systems, the Defense Depot Performance Measurement System (DDPMS) and measurements based on the Theory of Constraints (TOC). During personal interviews, ten depot managers were asked a series of questions designed to discover whether they understood the constituent measures of the two systems and whether they found the measures useful for competing with respect to quality, delivery, and cost. The authors analyzed the managers' responses to the questions and found that neither measurement system related well to the three competitive edges. Also, according to the managers, neither measurement system, as a whole, was driving depot performance. A new measurement system combining measures from DDPMS and TOC with other measures was recommended.

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       Significant                  Significant    Significance

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